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### ROSETTA'S FINAL MANOEUVRE

Project scientist Matt Taylor explains  
the last phase of ESA's comet mission

- ◆ VIRTUAL PLANETARIUM
- ◆ SKY AT NIGHT EPISODE
- ◆ OBSERVING GUIDES
- ◆ AND MUCH MORE...

### FIRST LIGHT

PrimaLuceLab's Airy  
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### THE LARGEST TELESCOPE

China's new radio dish  
makes its first observations

### AN OCEAN ON PLUTO?

Dwarf planet's crust points  
to freezing liquid below

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## This month's contributors include...

### BEN GILLILAND

SCIENCE WRITER



The man behind the *Metro's* MetroCosm science

section on how OSIRIS-REX will grab a space rock sample. *Page 68*

### ELIZABETH PEARSON

NEWS EDITOR



Elizabeth tells us everything worth knowing

about FAST, the largest single dish radio telescope on the planet. *Page 44*

### JAMEN PERCY

IAPY WINNER



Jamen won the Aurora category of IAPY 2015; here he

gives his top tips on how to process images of the Northern Lights. *Page 84*

### JASMIN FOX-SKELLY

ASTRONOMY AUTHOR



Jasmin reviews the myriad ways we are attempting

to deal with space junk, a growing problem in Earth's orbits. *Page 63*

# Welcome

Everything you need for the new season of astronomy



There's good news ahead! As we move into September the stars are out for noticeably longer: by the end of the month there'll be an extra two hours of darkness each night. Inside this

issue we have plenty to occupy you over the extra hours. On page 32, Paul Money looks forward to a spectacular season of stargazing, while on page 39 Vincent S Foster takes a focused view of the best deep-sky objects visible as summer's skies slowly slip away. Over on page 72, Will Gater reveals some of the tricks and tips astrophotographers use to create stunning images – invaluable if you're looking to improve your imaging skills.

Elizabeth Pearson takes a look at the world's largest radio telescope on page 44 – its 500m dish saw first light as we went to press – and cover this month's launch of the OSIRIS-REX sample-return mission to a near-Earth

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asteroid. On page 68, Ben Gilliland describes how it will collect dust from asteroid Bennu's surface and return it at the end of a seven-year voyage. And we stay close to our planet on page 63, where Jasmin Fox-Skelly examines new ideas emerging on how to keep Earth's orbital space clear of defunct satellites.

Enjoy the issue.

Chris Bramley Editor

PS Next issue goes on sale 22 September

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## Sky at Night LOTS OF WAYS TO ENJOY THE NIGHT SKY...



### TELEVISION

Find out what *The Sky at Night* team will be exploring in this month's episode on page 19



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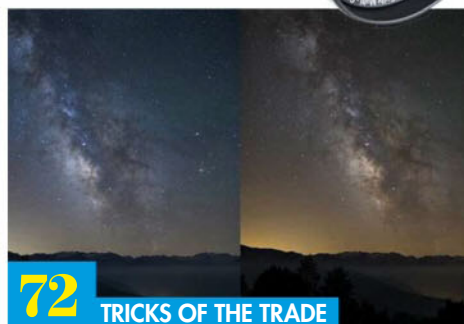
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## ROSETTA'S FINALE

The Rosetta spacecraft has been studying comet 67P/Churyumov-Gerasimenko since 2014, collecting data that is helping scientists piece together the story of the Solar System and the Universe. With the mission due to end on 30 September, we speak to Rosetta project scientist Matt Taylor about how it has gone, what we have learned and how it will end.



## EVERY MONTH VIRTUAL PLANETARIUM

With Paul Abel and Pete Lawrence

Take a tour of September's night-sky highlights with Paul and Pete.



## HIGHLIGHTS



## SKY AT NIGHT EPISODE

In July NASA's Juno space probe finally arrived in orbit around Jupiter, beginning its mission to study the gas giant. In that month's *Sky at Night* episode, Chris reports from NASA mission control as the probe reaches orbit, while Maggie explores how Juno will operate and what it can tell us.

## WHAT ARE COMETS MADE OF?



ESA and NASA videos look at the questions Rosetta is helping to answer, and the data it will be collecting during its final days.

## COLLECTING AN ASTEROID SAMPLE



Videos from the OSIRIS-REx team show how the spacecraft will operate and the science it will be carrying out at asteroid Benu.

## AND MUCH MORE...

- HOTSHOTS GALLERY
- EYE ON THE SKY
- EXTRA EQMOD FILES
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- EQUIPMENT GUIDE
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# A new light ● on Orion

This image of familiar M42 emphasises its beauty, but also shines new light on the star-forming processes within

VERY LARGE TELESCOPE, 12 JULY 2016

The Orion Nebula is a familiar sight for astronomers, visible from Earth to the naked eye as a fuzzy blob in the 'sword' of the constellation of Orion. But this latest image, provided by the HAWK-I infrared instrument on ESO's Very Large Telescope, looks deeper into the nebula than ever before.

Nebulae are massive clouds of gas and dust; this one, also designated M42, spans 24 lightyears and is located about 1,350 lightyears from Earth. Its relative proximity and size make it an ideal test subject for astronomers wanting to learn more about nebulae and the process of star formation.

This image of the Orion Nebula has surprised astronomers by revealing many of its low-mass stars for the first time, providing new clues as to how cosmic environments influence star formation. In fact, the VLT's infrared camera can see through the cosmic dust to reveal roughly 920 low mass stars, 760 brown dwarf candidates and 160 candidates for bodies known as isolated planetary mass objects.

This amounts to 10 times more substellar candidates than previously known. It would seem that M42 is producing low-mass stars at a faster rate than other star-forming regions, and contains a large number of objects that could be planets. However, because they are not orbiting stars, any planets that are discovered are unlikely to support life.

The observations show how infrared cameras and advancing technologies allow astronomers to view deeper into space and discover more about objects that have already been studied for millennia.

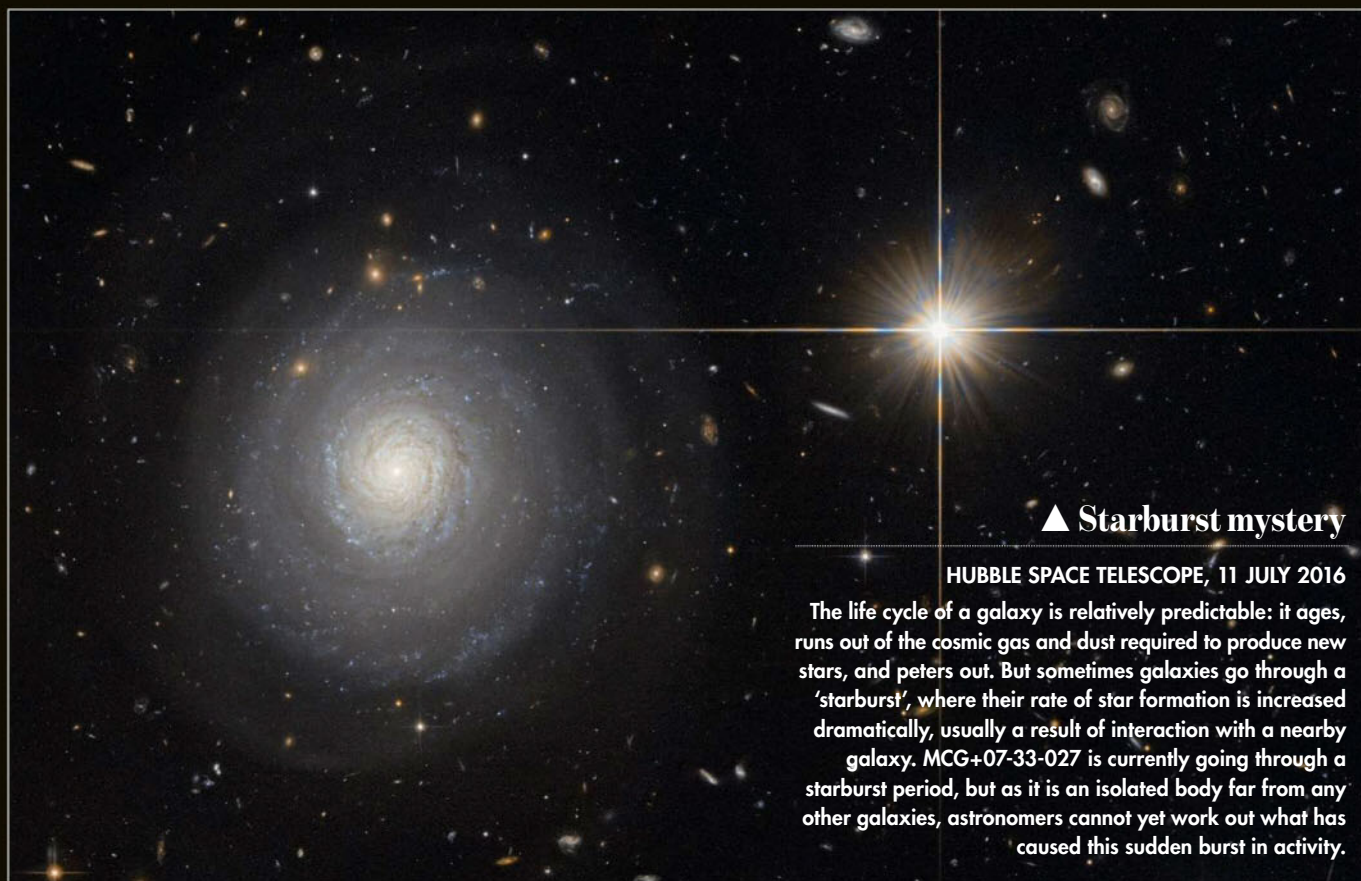
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### ▲ Starburst mystery

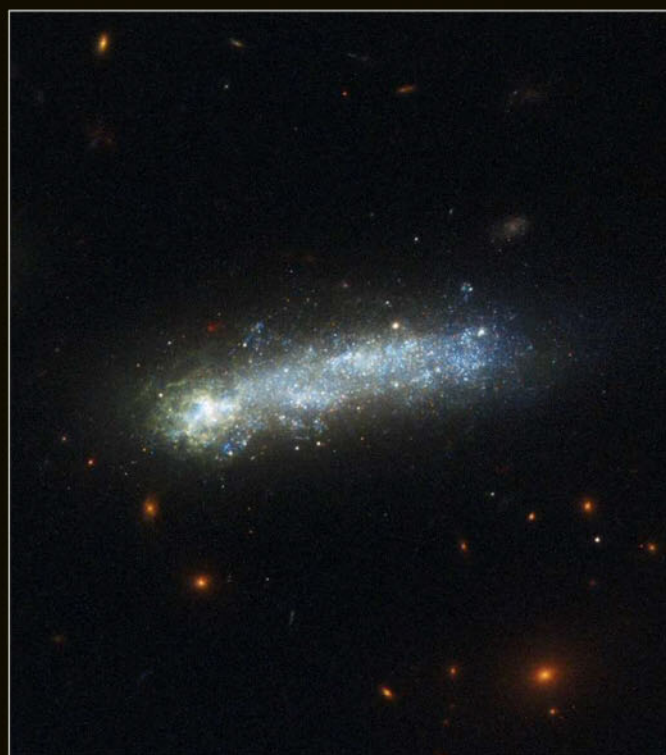
HUBBLE SPACE TELESCOPE, 11 JULY 2016

The life cycle of a galaxy is relatively predictable: it ages, runs out of the cosmic gas and dust required to produce new stars, and peters out. But sometimes galaxies go through a 'starburst', where their rate of star formation is increased dramatically, usually a result of interaction with a nearby galaxy. MCG+07-33-027 is currently going through a starburst period, but as it is an isolated body far from any other galaxies, astronomers cannot yet work out what has caused this sudden burst in activity.

### ▶ Extraterrestrial tadpole

HUBBLE SPACE TELESCOPE, 28 JUNE 2016

LEDA 36252 is what is known as a 'tadpole' galaxy, as a result of its bright head and long, tail-like shape. The head is so bright because it is going through a period of star birth, and it is thought that many galaxies develop this tadpole shape as they evolve.



### ◀ Solar loops

NASA SOLAR DYNAMICS OBSERVATORY, 5 JULY 2016

The loops seen in this image of the Sun are streams of plasma arcing along the magnetic field lines that jut out from active solar regions. These are known as coronal loops and form because the Sun's plasma is so energised that it erupts from the surface, before eventually following the magnetic field lines back home.





## ▲ Heart of the Crab

HUBBLE SPACE TELESCOPE, 7 JULY 2016

This is the centre of the Crab Nebula, clearly showing the Crab Pulsar, the uppermost of the two stars to the right of centre. This neutron star is the beating heart of the nebula, spinning 30 times a second and shooting out pulses of energy that expand the cosmic cloud out into space. The pulsar is so dense that its mass – equivalent to 1.4 Suns – is compacted into a body the same width as a large city.

## Comet cliffhanger ►

ROSETTA SPACECRAFT, 11 JULY 2016

This may be the last Rosetta image to make it into Eye On The Sky, as 30 September sees the spacecraft end its mission in a controlled descent to the surface of the comet, before communication with Earth is severed. This one shows the two lobes that form the duck-shaped comet's 'head' and 'body'. Bottom right is a fraction of the 900m-high cliff that forms the Hathor region, part of the 'head', while the top of the image shows the smoother patches of the 'body' section.







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# Bulletin

PLUS  
CUTTING

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EDGE

The latest astronomy and space news written by **Elizabeth Pearson**

Our experts examine the hottest new astronomy research papers

RR245's orbit is bringing it towards us, but even at perihelion it will be 5 billion km away

## New dwarf planet lies BEYOND PLUTO

The object's orbit takes it far outside of the Kuiper Belt

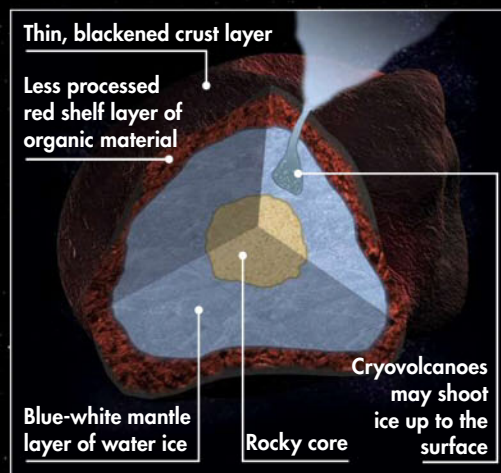
A NEW FAMILY member has been added to the Solar System. RR245, a dwarf planet, was recently found in the Kuiper Belt, the vast region of icy bodies on the outskirts of our planetary system that lies beyond Neptune.

RR245 has a highly elliptical orbit that takes 700 years to complete, swinging out to over 18 billion km (120 AU), 120 times the distance between Earth and the Sun. The dwarf planet is currently travelling towards its closest approach to the inner Solar System, but will take until 2096 to reach this perihelion point. Even then it will be 5 billion km (34 AU) from the Sun.

The exact size of the dwarf planet is currently unknown, though best estimates put it at around 700km in size.

"It's either small and shiny or large and dull," says Dr Michele Bannister of the University of Victoria in British Columbia. "Almost all of these icy worlds are painfully small and faint: it's really exciting to find one that's large and bright enough that we can study it in detail. [We sighted it as] a dot of light moving so slowly that it had to be at least twice as far as Neptune from the Sun."

Most dwarf planets of its size were either destroyed or thrown out of the Solar System as



Kuiper Belt objects appear to be a range of colours; one explanation is that they might have several layers

the giant planets moved out to their current positions. Along with Pluto and Eris, RR245 is a rare survivor in the Kuiper Belt.

"The icy worlds beyond Neptune trace how the giant planets formed and then moved out from the Sun. They let us piece together the history of our Solar System," says Bannister.

► See Comment, right



### COMMENT

by Chris Lintott

Not since the discovery of Pluto has the outer Solar System commanded so much attention. New Horizons is en route to a second Kuiper Belt object following its triumphant trip to Pluto, and controversy over the prediction of a large 'Planet Nine' is still raging.

RR245 won't help with the latter mystery; it's too close in to have its orbit perturbed by the putative giant planet. But that doesn't mean it's not in an interesting place.

Its orbit is dynamically linked to Neptune, the bully of the neighbourhood. During the time it orbits the Sun twice, Neptune goes around our star nine times, and it's the first body to be found in this particular configuration though many other so-called resonances exist.

This isn't the sort of detail that makes headlines, but it is a very specific clue to how bodies like RR245 have moved over time. Another piece of the Solar System's story is slotting into place.

CHRIS LINTOTT co-presents *The Sky at Night*



## NEWS IN BRIEF

### NOT-SO-LONELY WARM JUPITERS

A class of exoplanets known as warm Jupiters may not be as solitary as once thought. A study has shown nearly a third have planetary companions within their system. Current models assume that these hot gas giants formed far from their stars and migrated in later. However, if this were the case the other planets would have been flung out of orbit.

"Our findings suggest that a big fraction of warm Jupiters cannot have migrated to their current positions dynamically," says Chelsea Huang, from the University of Toronto.



### MARS 2020 ROLLS AHEAD

NASA has proceeded to the final development stages of the Mars 2020 rover, and will now start its final design and construction. The mission is aimed at ascertaining whether the Martian surface might once have been suitable for microbial life and will borrow heavily from the Curiosity rover's design to cut costs. However, it will have a completely new set of science instruments to run in-situ experiments as well as creating sample caches that a future mission could pick up for return to Earth.



ISTOCK, NASA/GSFC/ARIZONA STATE UNIVERSITY, NASA/JPL-CALTECH, NASA/JPL-CALTECH/D. LANG/DUNLAP INSTITUTE, KAREN TERAMURA/UH IFU/JAMES O'DONOGHUE, ESA/NASA, NASA

### IMBRIUM BASIN

Various grooves and gashes surrounding the Imbrium Basin were used to estimate the size of the impactor

# THE MOON'S BLACK EYE

The Imbrium Basin was likely created by a protoplanet collision

AN ASTEROID TWICE the size of Wales slammed into the Moon 3.8 billion years ago, leaving it with a black eye. That's the finding of a study that says a 250km wide meteor created the Imbrium Basin – the region that appears to be the right eye of the fabled Man in the Moon. And it seems 250km is a low estimate. "It's possible that it could have been as large as 300km," says Pete Schultz, from Brown University.

The Imbrium Basin is a dark basaltic plain in the Moon's northwestern quadrant. Though it has long been known that the region was created by a huge impact early in lunar history, the precise size of the impact has remained uncertain.

A set of ridges from a region to the northwest of the crater – which can easily be seen with a small telescope – might hold the clues needed. These ridges lie up-range of the asteroid's presumed trajectory, meaning they were created before the strike that caused the main crater.

To help explain these, the team at Brown simulated an impact by firing projectiles at a target at 25,750km/h, recording how they fared with high-speed cameras. These

experiments showed that when an impactor is large enough, it breaks apart on first contact with the surface.

This suggests that when the meteor first hit the lunar surface, part of it broke off and scoured the surface creating the observed grooves. Using this new evidence the team were able to estimate the size of the impactor directly from the geology for the first time, giving a mass 10 times greater than previous approximations based on computer programs.

"This is the first estimate for the Imbrium impactor's size that is based largely on the geological features we see on the Moon," says Schultz. "We show that Imbrium was likely formed by an absolutely enormous object, large enough to be classified as a protoplanet."

Protoplanets were the embryonic bodies that built up to form the Solar System, but any remaining after the planets' birth have long since been destroyed. Studying the craters they left behind, however, can give us insight into their size and number.

"The large basins we see on the Moon and elsewhere are a record of lost giants," says Schultz.

<https://www.brown.edu>



## NEWS IN BRIEF

### UK MARKS £1.15M FOR SPACEFLIGHT

The UK government is increasing its commitment to spaceflight by allocating a fund of £1.15m to research the plausibility of launching small satellites and sub-orbital flights from Britain. The UK Space Agency announced its intention to build Europe's first spaceport in 2014. The initiative is a key part of the UK government's aim to establish Britain as a leading power in the world's space industry.



### HEART COST OF LUNAR TRAVEL

Flying to the Moon may have taken its toll on Apollo astronauts, many of whom now experience cardiovascular problems. Recent analysis of the lunar explorers' heart troubles has shown they may stem from exposure to high-energy galactic cosmic rays during their Moon trips.

"We know very little about the effects of deep space radiation on human health, particularly on the cardiovascular system. This gives us the first glimpse into its adverse effects on humans," says Michael Delp from Florida State University.



## Missing X has finally been found

The stellar structure lies in the heart of the Milky Way

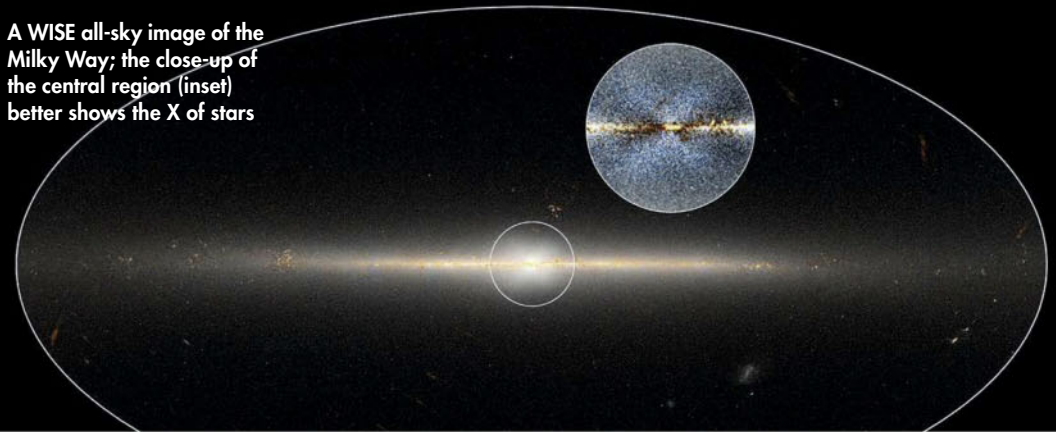
A LONG-SUPPOSED X-shaped structure of stars has been found in our Milky Way's centre. Similar crosses have been found in other spiral galaxies, created by the motion of stars within the central bulge. However, it was only seen in our Galaxy when astronomers reinterpreted data captured by WISE in 2009. The presence of the X in the bulge tells us that the Milky Way cannot have undergone a merger with another galaxy in

the past few billion years, as this would have erased any such structure.

"We see the X-shape and boxy morphology so clearly in the WISE image and this demonstrates that internal formation processes have been the ones driving the bulge formation," says Melissa Ness from the Max Planck Institute for Astronomy in Heidelberg.

<http://sci.esa.int/xmm-newton/>

A WISE all-sky image of the Milky Way; the close-up of the central region (inset) better shows the X of stars



## THE GREAT RED SPOT IS WARMING JUPITER

THE GREAT RED Spot appears to be heating Jupiter's unusually warm upper atmosphere, according to the latest infrared images of the gas giant. The atmosphere 800km above Jupiter's cloud layer has temperatures similar to those found above the Earth, despite being five times more distant from the Sun.

It was thought that a non-solar source must be providing the needed energy, but what this could have been had proved elusive.

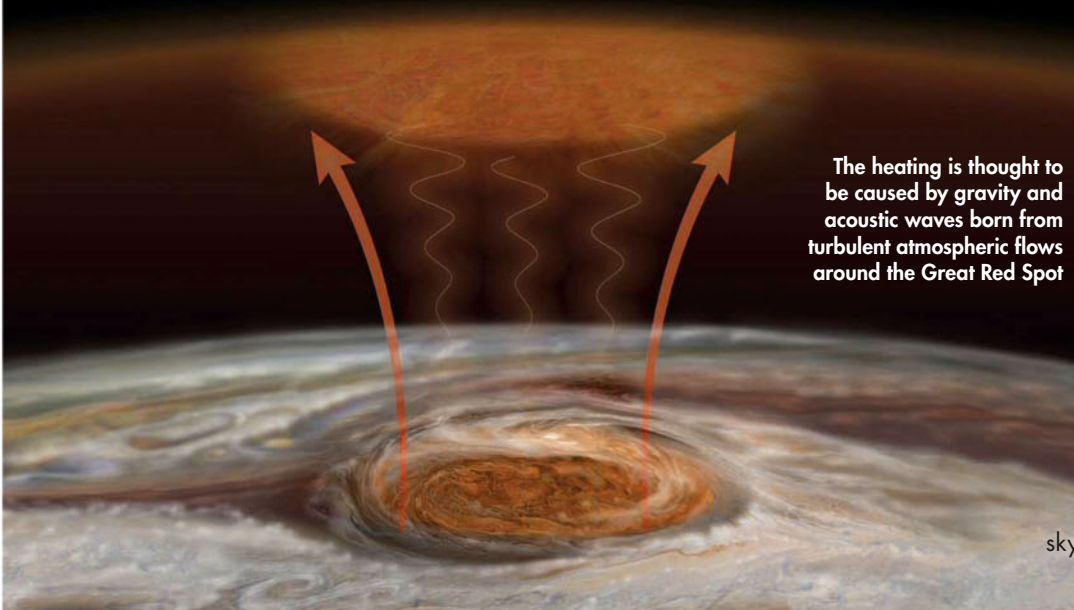
"The Great Red Spot is a terrific source of energy to heat the upper atmosphere at Jupiter, but we had no prior evidence of its actual effects

upon observed temperatures at high altitudes," says Dr Luke Moore from Boston University.

The team found that temperatures at high altitude spiked at latitudes and longitudes that corresponded with the Great Red Spot. It seems likely that such storms are responsible for heating not only Jupiter, but other gas giants and exoplanets too.

"The extremely high temperatures observed above the storm appear to be the smoking gun of energy transfer," says James O'Donoghue, also from Boston University. <http://irtfweb.ifa.hawaii.edu>

The heating is thought to be caused by gravity and acoustic waves born from turbulent atmospheric flows around the Great Red Spot





## CUTTING

Our experts examine the hottest new research

## EDGE

## Our Galaxy's runaways

Why some stars are flung out of the Milky Way



**T**here are runaway stars in the Milky Way. High above our Galaxy's disc, in the halo of material that surrounds it, stars have been spotted speeding away at more than 300km/s – so quickly that they will be able to escape the Milky Way's gravitational pull. Twenty have so far been found, but there are undoubtedly many more.

A new paper provides evidence that the fate of these escapees is tied to a different group of special stars, those in tight orbits around the supermassive black hole that lies in the centre of the Galaxy. Some of these have orbits that take them as close as a few lightdays to the centre, and understanding how they ended up on such confined orbits is a real puzzle.

Ladislav Šubr and Jaroslav Haas of Charles University in Prague have a model that explains both of these sets of stars, which they say began life as binary stars, born in a disc of material around the black hole. That seems plausible, as star formation in the galactic centre is common and in many circumstances binary stars are more common than single stars like the Sun.

▲ Disruptions to the orbits of binary systems could be causing some stars to be expelled from the Milky Way



**CHRIS LINTOTT** is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

In the computer model the authors set up, the stars start life in a disc around the supermassive black hole. Rather than orbit quietly in perpetuity, though, the interplay of gravity between the stars in the disc starts to create interference, sending some of them into highly elliptical orbits.

This is a fairly well understood process, called the Kozai-Lidov mechanism, the influence of which has been observed in the motion of Solar System bodies and in a few exoplanetary systems too. Here, it's the inclusion of the binary stars that makes a difference.

Once thrown onto an eccentric orbit, the binaries can be ripped apart from each other. One star ends up tightly bound to the black hole, whereas the other is sent flying out into the cosmos. At a stroke, the model explains both populations of stars. The predicted velocities of the escaping high velocity stars match well to what's observed, though the

**“One star ends up tightly bound to the black hole, the other is sent flying out into the cosmos”**

details – such things as the number of stars we should expect to see and exactly what the observed velocity should be – are very dependent on the assumed properties of the initial disc of stars and on the shape of the galaxy.

Being scattered in this way is even good news for the stars. There's evidence that supermassive black holes can rip stars apart, a process we've seen signs of in nearby galaxies. Yet at the end of this process, both stars are safe: one parked on a stable orbit that's difficult to disrupt, close to the black hole, and the other expelled from the system altogether.

Despite these excellent results, there is, as ever, more work to do. The disc that's in the model doesn't end up looking like the young stars that are observed in the galactic centre, and new observations will help pin down the population of escaping stars. The model's already a neat explanation of two very different phenomena, something very satisfying indeed.

**CHRIS LINTOTT** was reading... *The properties of hypervelocity stars and S-stars originating from an eccentric disc around a supermassive black hole* by Ladislav Šubr and Jaroslav Haas.

Read it online at <https://arxiv.org/abs/1606.09247>



# Star's snowline bursts into view

It's the first time a snowline has been seen in a protoplanetary system



▲ Snowlines usually exist within 3 AU of a star; around V883 Orionis, it has been pushed out to 40 AU

THE POINT BEYOND which water freezes in a growing planetary system has been imaged for the first time. This boundary, called the snowline, is usually found around three times the Earth-Sun distance from the star, which is too close to be observed. However, the star V883 Orionis is experiencing a time of intense brightening that has pushed the snowline in its protoplanetary disc over 13 times farther out, allowing it to be observed by scientists using ALMA.

Stellar outbursts like this appear to be a common part of most planetary systems' evolution. As the position of the snowline is vital to determining if a growing planet is rocky or gaseous, this find is an important step in understanding how planets form. [www.almaobservatory.org](http://www.almaobservatory.org)

## NEWS IN BRIEF

### HOW TO MAP A BLACK HOLE

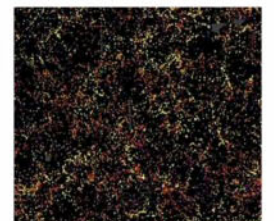
Astronomers may soon be able to give black holes an X-ray, thanks to the recently proved existence of a surrounding gravitational vortex. General relativity states that as a black hole spins it creates a gravity whirlpool around it, which churns up the gas within causing it to emit X-ray light. By observing the glow, researchers will finally be able to see the inside of an accretion disc rather than interpreting the motion of matter around it.

"We are directly measuring the motion of matter in a strong gravitational field near to a black hole," says Adam Ingram of the University of Amsterdam.



### LARGEST GALAXY ATLAS RELEASED

The largest ever three-dimensional map of galaxies has been completed using Sloan Digital Sky Survey III data, allowing researchers to trace dark energy throughout the Universe. "We have spent five years collecting measurements of 1.2 million galaxies over one quarter of the sky," says Jeremy Tinker of New York University.



A: ANGELICH (NRAO/AUI/NST/AJMA (ESO/NAO/NRAO), NASA/JPL-CALTECH/SWRI/MSS; RICHARD NOWELL/CAROLIN CARDAMONE, ESA/ATG MEDIALAB, DANIEL EISENSTEIN AND SDSS III

## JUNO'S FIRST IMAGES ARE HERE

THE JUNO SPACECRAFT has sent back its first in-orbit image of gas giant Jupiter, taken with the visible light camera JunoCam. The shots were captured when the craft was at a distance of 4.3 million km, halfway towards the farthest part of its initial capture orbit. Juno is now past this point and heading back towards Jupiter with all its science instruments switched on.

"This scene from JunoCam indicates [the spacecraft] survived its first pass through Jupiter's extreme radiation environment without any degradation and is ready to take on Jupiter," says Scott Bolton, Juno's principal investigator. "We can't wait to see the first view of Jupiter's poles."

<https://www.missionjuno.swri.edu>



This view is made from several of the first images recorded by Juno after entering Jovian orbit

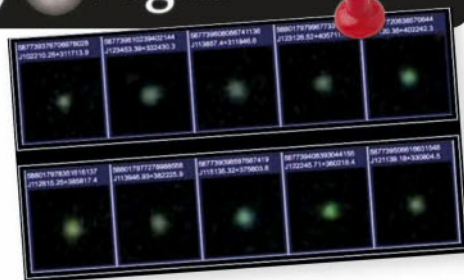
## Looking back The Sky at Night

### 7 September 2008

On 7 September 2008 the *Sky at Night* team looked back over the first year of a new citizen science initiative – Galaxy Zoo.

The initiative was set up in 2007 by Oxford University astrophysicists Kevin Schawinski and Chris Lintott. They needed to classify the shape, or morphology, of around one million galaxies imaged during the Sloan Digital Sky Survey; a tedious task that would have taken one person years to complete.

Their solution was to set up a website named Galaxy Zoo, through which over 100,000 volunteers classified the catalogue within a mere 175 days. This revealed new classes of galaxies, such as a hitherto unknown population of blue ellipticals and strange compact galaxies that have become known as 'green peas' due to their appearance in images.



▲ Some of the new 'green pea' galaxies discovered by Galaxy Zoo volunteers

The project has grown since then, inspiring the creation of dozens of similar citizen science projects in astronomy and beyond.



## CUTTING

Our experts examine the hottest new research

## EDGE

## Cracking Pluto's shell

Deep fissures in the distant dwarf planet's crust seem to point towards a subsurface liquid ocean



One of the great surprises of the New Horizons flyby of Pluto last July was the evidence for a diverse range of geological activity across its face. Much of this activity has been within volatile ices of nitrogen, carbon monoxide and methane on its surface, but there are also signs of geological activity within Pluto's bedrock of hard water-ice. The face of Pluto is marked by troughs and scarps, often hundreds of kilometres long and up to 4km deep. It's not yet known how old these features are, but they still appear crisp and not yet heavily degraded, and so are thought to be pretty recent.

Various processes can drive tectonic activity on a world – the tidal forces experienced by the icy moons Europa or Enceladus as they orbit their massive planet, for example. But tidal forces in the Pluto-Charon system are essentially nil today, as over time the pair have become tidally locked to each other, meaning that they turn synchronously so that the same faces are always towards each other.

There is another curious fact of Pluto's tectonic activity. The young features we've seen are thought to be a kind of landform called 'extensional faults', but we don't see any accompanying compression features. So it seems as though the whole crust of Pluto is expanding.

▲ The apparent crispness of the surface features on Pluto suggest that they formed relatively recently



**LEWIS DARTNELL** is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* ([www.the-knowledge.org](http://www.the-knowledge.org))

One mechanism that could account for this global swelling is if Pluto has a subsurface ocean that is slowly freezing. Anyone who's ever forgotten they left a bottle of water in the freezer will know that it expands and bursts as the water turns to ice. And this same process would explain the extensional faulting seen across the whole face of Pluto from global expansion. So is this a feasible explanation? And could these extensional faults still be forming right now, meaning that Pluto sports an ocean of liquid water deep beneath its surface even today?

To explore this, Noah Hammond and his colleagues at Brown University have used data from New Horizons to build a computer simulation of Pluto's interior and how it would have developed over the Solar System's history. They modelled the dwarf planet with a core of silicate rock, surrounded by water, and included all the important factors like warming of Pluto's innards with radioactive decay and the conduction of heat out to the surface.

**“The features we've seen are thought to be a kind of landform called extensional faults”**

The outcome depends on the thermal properties of the rocky core, which we don't know very well. But Hammond did find that if the ocean freezes to form a thick shell of ice, then the pressure causes another kind of water-ice to form. 'Ice II' is denser with a different crystal structure to the 'normal' ice you're familiar with from your home freezer, and in fact shrinks rather than expands. This would mean that Pluto would contract and we should see compressional tectonic features on the surface – which we don't. The conclusion Hammond comes to, therefore, is that the most likely explanation is that the interior of Pluto is indeed warm enough to sustain a liquid water ocean today.

This is a great example of planetary detective work based on the New Horizons close encounter that only lasted a matter of hours. It means that if you lived on Pluto, you'd find that your world really is getting bigger.

**LEWIS DARTNELL** was reading... *Recent tectonic activity on Pluto driven by phase changes in the ice shell* by Noah P Hammond, Amy C Barr, Edgar M Parmentier  
Read it online at <http://arxiv.org/abs/1606.04840>



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# What's on

Our pick of the best events from around the UK

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MONTH



▲ Herstmonceux was once home to the Royal Observatory Greenwich

## Herstmonceux Astronomy Festival 2016

The Observatory Science Centre, Herstmonceux, Hailsham, East Sussex, 2-4 September

Set in the grounds of the Grade II-listed Observatory Science Centre, former home of the Royal Observatory Greenwich, the annual Herstmonceux Astronomy Festival is in its 12th year. The full 2016 programme features lectures, observing, hands-on workshops and trade stalls. Astronomy author and broadcaster Ian Ridpath will deliver a lecture on the opening night of the festival, followed by observing sessions and tours of the telescopes.

The programme for Saturday and Sunday includes four lectures each day, planetarium shows, solar observing and

a special 'Meet the NASA scientist' event with JPL engineer Dr Christopher Jacobs. There will also be opportunities to learn about the history of the centre and take a look through its historic telescopes, weather permitting.

Camping is available onsite and there is also alternative accommodation within walking distance of the festival. Proceeds of the event go towards the upkeep of the site and its telescopes. For more information about ticket prices, camping and weekend registration, go online.

[www.the-observatory.org](http://www.the-observatory.org)

## BEHIND THE SCENES THE SKY AT NIGHT IN SEPTEMBER

**BBC Four**, 11 September, 10pm (first repeat **BBC Four**, 15 September, 7.30pm)\*



The small red dwarf Proxima Centauri is the nearest star to our own

### CAN WE TRAVEL TO THE STARS?

Jim Al-Khalili joins *The Sky at Night* to investigate the possibility of sending a spacecraft to our nearest neighbouring star. As well as looking at the technology required to get there, the team examine observations that suggest our local stars are more interesting than we imagined.

\*Check [www.bbc.co.uk/skyatnight](http://www.bbc.co.uk/skyatnight) for subsequent repeat times



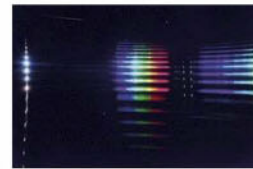
## Astronomy in Pre-Columbian Civilisations

Augustine United Church, 41 George IV Bridge, Edinburgh, 9 September, 8pm

Vanessa Smer-Barreto of the Royal Observatory Edinburgh looks at the influence of astronomy on the architectural and cultural characteristics of Mayan, Incan and Aztec societies. The talk will explore how the movements of the Sun and Moon, eclipses and the Milky Way played an important role in the politics of the times, and the legacy these cultures have left behind. Admission is free. [www.astronomyedinburgh.org](http://www.astronomyedinburgh.org)

## Reading the Secrets in Starlight

Charterhouse Observatory, Somerset, 10 September, 10am



Splitting starlight into its visual spectrum enables astronomers to uncover the properties of stars and galaxies, and new kit and software are bringing costs down and opening the

science of spectroscopy to amateurs. This one-day course will help you to get started, including what equipment to use and how to interpret the results. Places are £20. [www.exoplanetproject.co.uk](http://www.exoplanetproject.co.uk)

## The Giants of the Universe

West Didsbury Astronomical Society, William Hulme's Grammar School, Manchester, 12 September, 7pm



Galaxy clusters are the largest stable objects that we know of in the Universe. This talk by the University of Manchester's Monique Henson will look at how cosmologists can create simulations of galaxy clusters to study, and what these

studies can reveal about dark matter and the evolution of the Universe. Admission is free.

[www.wdas2.com](http://www.wdas2.com)

## MORE LISTINGS ONLINE

Visit our website at [www.skyatnightmagazine.com/whats-on](http://www.skyatnightmagazine.com/whats-on) for the full list of this month's events from around the country.

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Photo courtesy Graham Smith, www.ukastroshow.com

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## New and Events September 2016

The Autumn Equinox Star Party - [www.starparty.org.uk](http://www.starparty.org.uk) - is approaching. Join **The Widescreen Centre** at Kelling Heath Holiday Park the weekend of October 1st 2016. October 14-15th, **IAS - the International Astronomy Show** returns to Stoneleigh Park. Widescreen will be there on booths 35-36. For tickets: [ukastroshow.com](http://ukastroshow.com)

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# A PASSION FOR SPACE



with **Maggie Aderin-Pocock**

*The Sky at Night* presenter discusses the rise of the large telescope, and the latest record breaker

**T**he telescopes of the world are getting bigger. I remember around 20 years ago hearing of the first 8m class of telescopes: they put my handmade 6-inch reflector to shame but hailed the new era of the big telescope. You cannot imagine my joy years later when I got an opportunity to work on the 8m Gemini South telescope in Chile. I also remember a visit to the Very Large Telescope (VLT) – four 8m telescopes that work as a single instrument; it boggled the mind.

Now, years later we are seeing the successor of the VLT. The E-ELT, or European Extremely Large Telescope, is being constructed as we speak and is due to see first light in 2024. Radio telescopes are getting the larger treatment too, with the Square Kilometre Array (SKA) underway. It will give us unprecedented views of the Universe via an array of telescopes spread across dual sites in South Africa and Australia. The first phase of construction is due to start soon, and first light is expected by 2020 with a cut down array.

There is so much potential out there that it is sometimes hard to wait for it to all come to fruition, which makes it

**FAST's dish is a massive 500m across, making it the largest telescope on Earth**



all the more exciting to write about a goliath that is here right now: the FAST radio telescope, which has just been completed in southern China. FAST – the Five Hundred Meter Aperture Spherical Telescope – is now officially the largest telescope on Earth. Its immense dish overtakes the record that was held by the 305m-diameter Arecibo Observatory radio telescope in Costa Rica for 53 years.

## The trick of the dish

FAST has a physical diameter of 500m, which gives it an effective collecting area of 70,000 square metres – that's around 30 football pitches to you and me. As well as being huge, FAST is up to 10 times more sensitive than its nearest rival in the radio telescope world, due to

its deformable fixed primary mirror. Rather than relying on a fixed spherical surface, FAST's moveable reflective surface can be shaped into a parabola, which will enable us to view more objects at a much greater distance, and bring them to a much sharper focus.

It is early days for FAST, but when it is fully calibrated it will be turning its attention to light from the early Universe. Targets here include looking for

as yet undetected pulsars, the search for low frequency gravitational waves, and trying to find signals produced by alien civilisations.

To help with these endeavours, FAST's surroundings are being modified to minimise interference from other radio signal sources. To achieve this a village has been relocated and all people living within a 5km radius of the site are being moved to reduce the levels of radio noise.

FAST is an excellent step in the movement towards the ever-bigger telescope and will tide us over as we wait with baited breath for the full SKA to get up and running in the near future. **S**

Maggie Aderin-Pocock is a space scientist and co-presenter of *The Sky at Night*



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JON CULSHAW'S



# EXoplanet EXCURSIONS

Jon heads for a scorching rocky world where one year lasts a single Earth day

**T**here's a particular fascination with those exoplanets in very close proximity to their parent stars. Their molten ferocity combined with the blistering pace of their orbits shows us the most hellish extremes in which an exoplanet can exist.

Kepler 10b was the first confirmed rocky exoplanet to be discovered, following the impressive list of 'hot Jupiters' found previously. Kepler 10, the parent star of the system we're set to visit, is also known as KOI-72. It is a G-class star similar to our Sun, with a slightly larger radius but a little less mass – though it is almost double the age at 10.4 billion years.

The star lies 564 lightyears from Earth in the constellation of Draco, and its age brings a feeling of impending red giant status. From Earth, Kepler 10's apparent magnitude is +11.0 and so is comfortably visible using a small telescope.

Kepler 10b makes for a fascinating comparison with Mercury. It is much closer to its star, 20 times closer in fact, so its orbit is a desperately fast 20 hours. That means it experiences one year in less than one Earth day! The planet is tidally locked to the star, and with my ship stabilised at 1/10th of the distance that the Moon orbits Earth, we have a marvellous perspective.

The side of this tidally locked planet nearest the star emanates a piercing yellow glow not much dimmer than the star itself. Temperatures on this half of the planet are believed to be around 1,560°C. The opposite side of this world glows with a slightly cooler vivid orange. Kepler 10b has the curiously pleasing look of a lemon and peach hybrid.

Steering the Perihelion closer still brings the breathtaking and fearsome features of this world sharply into view. The harsh, volcanic existence of this planet belches streams of all manner of noxious matter into swirls around it, like toxic Jovian bands. The level of volcanic activity and molten oceans of lava give rise to a highly electrically active atmosphere which is eerie and breathtaking to observe. Astronomers believe there could be as many as two trillion lightning flashes in just a few hours. From our observing distance they resemble flickering oxyacetylene spider's webs.

Reversing the Perihelion to a position where Kepler 10b transits its parent star is a jaw dropping sight. From this position the star appears 20 times larger than the Sun does in Earth's skies. The transiting world doesn't appear solid black as the Moon does during solar eclipses on Earth: it smoulders with the orange glow of volcanic activity speckled with the strobing light show of perpetual lightning strikes.

I'll continue my reverse flight away from Kepler 10b for now. Such a hellish

exoworld is best observed at a distance where violence settles into a more distantly serene context. I'm not too far from the neighbouring planet Kepler 10c, which may be worth a visit in the future.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*



BBC

# Sky at Night

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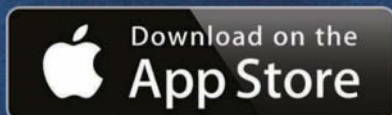
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# ROYAL OBSERVATORY GREENWICH



Venus Rising © Ivan Slade

## INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

Astronomy Centre, Royal Observatory Greenwich  
17 September 2016 – 25 June 2017

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## This month's top prize: four Philip's books

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Robin Scagell and David Frydman's *Stargazing with Binoculars* and Heather Couper and Nigel Henbest's *Stargazing 2016*

## PHILIP'S



## SOCIAL MEDIA

WHAT YOU'VE BEEN SAYING ON TWITTER AND FACEBOOK

Have your say at [twitter.com/skyatnightmag](https://twitter.com/skyatnightmag) and [facebook.com/skyatnightmagazine](https://facebook.com/skyatnightmagazine)

@skyatnightmag asked: If you could send a radio message out to the Galaxy, what would you say?

**Michael Cotton** Could we have Elvis back now please? Ta muchly!

@paulatan1972 Is your world as mad as this one?

@handronicus101 Turn back before its too late.

@marviesam75 "Hello... Is this thing on? Can they hear me?"

**Glen Turner** Do you like cheese?

**Graham Finch** Had an accident that wasn't your fault, or been mid-sold PPI?

NASA/JPL/SPACE SCIENCE INSTITUTE

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## MESSAGE OF THE MONTH

### Sublime Saturn showcases the scale of the cosmos

I'm fairly new to astronomy, and on the evening of 8 July at around 11pm I managed to get my first view of Saturn and its rings through my second-hand Celestron Astromaster 76EQ. I was immediately star struck and aimed my iPhone 5s camera down the eyepiece to take what is probably the worst, blurriest and least detailed photograph of Saturn – and indeed the night sky! Despite all that it still captured Saturn, albeit faintly, and its awe inspiring rings. As soon as I saw this photo I immediately thought of the similarity between it and the 'Pale Blue Dot' photo of Earth. It really does put the Universe in perspective: we have all of these amazing close-up images of giant stars and planets but, due the scale of space, when we look up into the night sky with our own eyes everything appears as small as a spec of dust.

**Jake Walpole, via email**

*A great first picture, Jake. The value of astronomy doesn't just lie in fantastic images – its ability to reveal the true scale of the cosmos is also very important. – Ed*



▲ Left: Jake's picture of Saturn; right: The pale blue dot of Earth as imaged by the Cassini spacecraft in 2006

## That's quite a workout



This is just a lighthearted photo of me enjoying my subscription to your wonderful publication. Who says you can't combine the cerebral with the physical?

**Callum McDougall, via email**

*This has to be the most unusual way to read the magazine, Callum, top marks! – Ed*

## Eco-space tourism

I enjoyed the postcards given away with the August issue. However, the thought that space tourism could get big in the coming decades is concerning in terms of climate change. Vast amounts of hydrocarbons are used either directly in rocket fuels or indirectly in the manufacture of the components. Our tentative steps into space have already littered Earth's orbits with junk, and space tourism would make an irresponsible contribution to greenhouse gases in our atmosphere for the pleasure of a few.

**Derek Smith, London**

*Space's impact on climate is a crucial consideration, Derek. It should remain at the forefront of development as technologies advance. – Ed*

## A lucky glimpse

I awoke at 3am one morning in July and happened to glance out of the window when I was rewarded with this magnificent view of noctilucent clouds in the northeast. This was the first time that I had seen these ethereal clouds during many years of searching for them after sunset.

**Chris Pointer, via email**

*A wonderful display to have captured, Chris. I hope you took the chance for some early-morning stargazing too. – Ed*



The NLCs on show from Chris's window



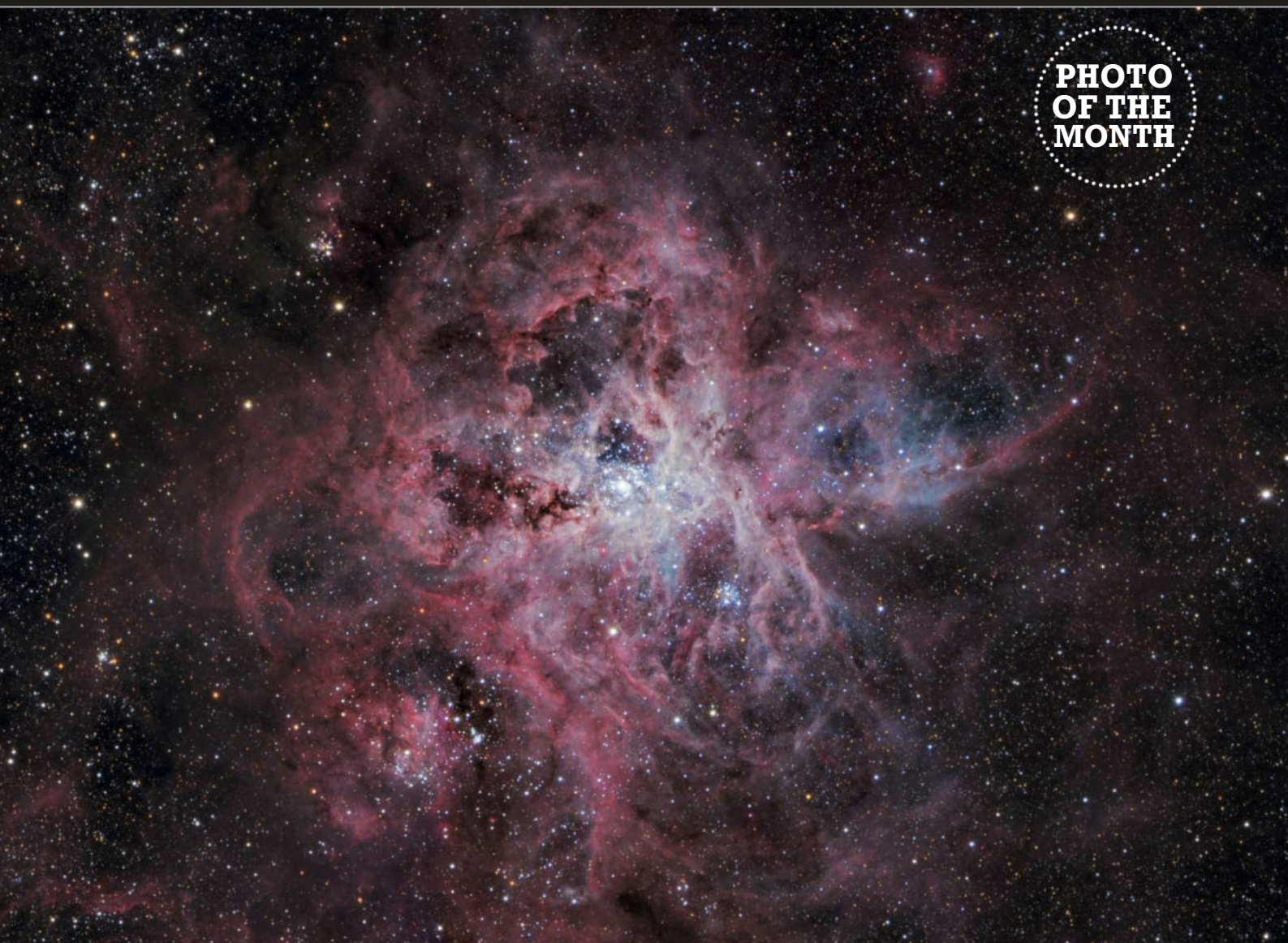
# Hotshots

This month's pick of your very best astrophotos

**YOUR  
BONUS  
CONTENT**

A gallery  
containing these  
and more of your  
stunning images

**PHOTO  
OF THE  
MONTH**



## ▲ The Tarantula Nebula

WARREN KELLER, STAR SHADOWS REMOTE OBSERVATORY SOUTH, CHILE, JUNE 2016

**Warren says:** "The dark skies of Chile's Atacama Desert and the 0.4-arcsecond seeing yield amazing amateur images of the night sky. This spring, I assembled a three-panel mosaic for each of the data sets (red, green, blue, hydrogen-alpha, oxygen III) using data that was captured with the help of my colleagues S Mazlin, S Menaker and J Harvey, before blending the masters into what I hope is an artful and interesting version of this iconic object."

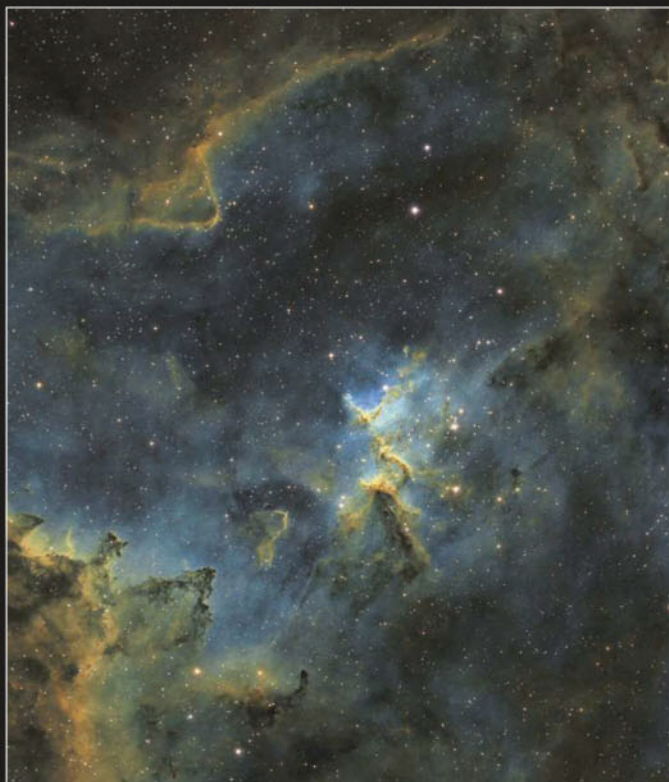
**Equipment:** Apogee Alta U9 CCD camera, RCOS 16-inch Ritchey-Chrétien, PlaneWave Ascension 200HR mount.

**BBC Sky at Night Magazine says:** "This is a fantastically crisp capture that has a haunting quality about it. The wisps of the nebula are clearly visible, as are the hot, bright blue stars and seemingly endless galaxies stretching out into space."



**About Warren:** "As a child of the 60s, I loved *Star Trek*, *Lost in Space* and *2001: A Space Odyssey*. I'd wake up at dawn to watch Mercury, Gemini and Apollo launches. Aged 12, I bought an 8-inch Newtonian and I remember being gifted with Fred Hoyle's book *Astronomy* which had a beautiful picture of the Dumbbell Nebula on the cover. I thought that one day I'd love to take an image like that!"



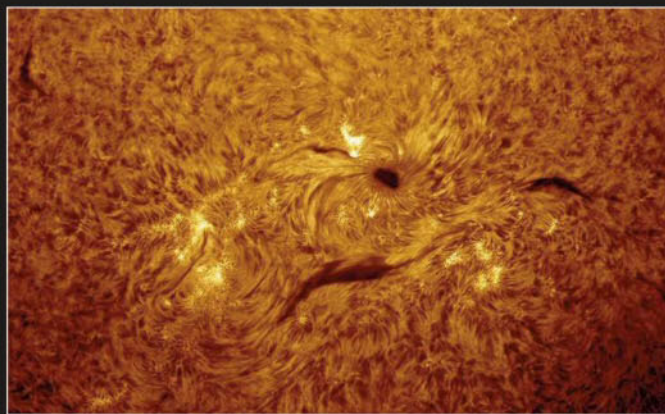


### ▲ Open star cluster Melotte 15

CHRIS HEAPY, MACCLESFIELD, 15 JUNE 2016

**Chris says:** "Melotte 15 represents the powerhouse of the vast Heart Nebula in Cassiopeia: a cluster of young hot stars eroding the molecular cloud containing them. This colourful image is a narrowband composition in the Hubble Palette."

**Equipment:** Atik 490EX monochrome CCD camera, Moravian Instruments G4-16000 CCD camera, Tele Vue NP127is refractor, 10 Micron GM 2000 HPS mount.



### ▲ Solar active region AR 2553

EWAN HOBBS, HASTINGS, 15 JUNE 2016

**Ewan says:** "I was shooting through another hazy sky, although the 6-inch seems to be able to get past some of this issue and allows fairly good captures to be had. If there is any chance of solar imaging I will be outside giving it a go: lack of spots does not mean lack of action!"

**Equipment:** DMK 21AU618 CCD camera, Tecnosky 6-inch achromat refractor, Sky-Watcher AZ-EQ6 GT mount.



### ▲ The Sunflower Galaxy

JOSÉ J CHAMBÓ, CIUDAD REAL, SPAIN, 4 JUNE 2016

**José says:** "This image was taken from a star party where I was able to take advantage of a really dark sky and the power of a Newtonian telescope. It is a nice wide field showing the fine arms of the galaxy."

**Equipment:** Canon EOS 100D DSLR camera, GSO 8-inch Dobsonian.

### Rising Strawberry Moon

MARY SPICER, NORTH OXFORDSHIRE, 20 JUNE 2016

**Mary says:** "The full 'Strawberry' Moon coincided with the summer solstice so I was very keen to observe it. It was the most vivid pink colour I've ever seen during a moonrise! Within five minutes it had gone behind cloud again, so I was extremely lucky that I got a gap in the clouds at exactly the right time."

**Equipment:** Canon EOS 1100D DSLR camera, 18-55mm lens.







### ▲ The Milky Way

ALEX CONU, CATHEDRAL COVE,  
NEW ZEALAND, 1 MAY 2016

**Alex says:** "Most people visit Cathedral Cove during daytime, but I decided to go there at night, and for a good reason. This was my first contact with the southern skies and it was like being reborn from an astronomical point of view."

**Equipment:** Canon EOS 5D Mk III DSLR camera, Zeiss Otus 28mm lens.

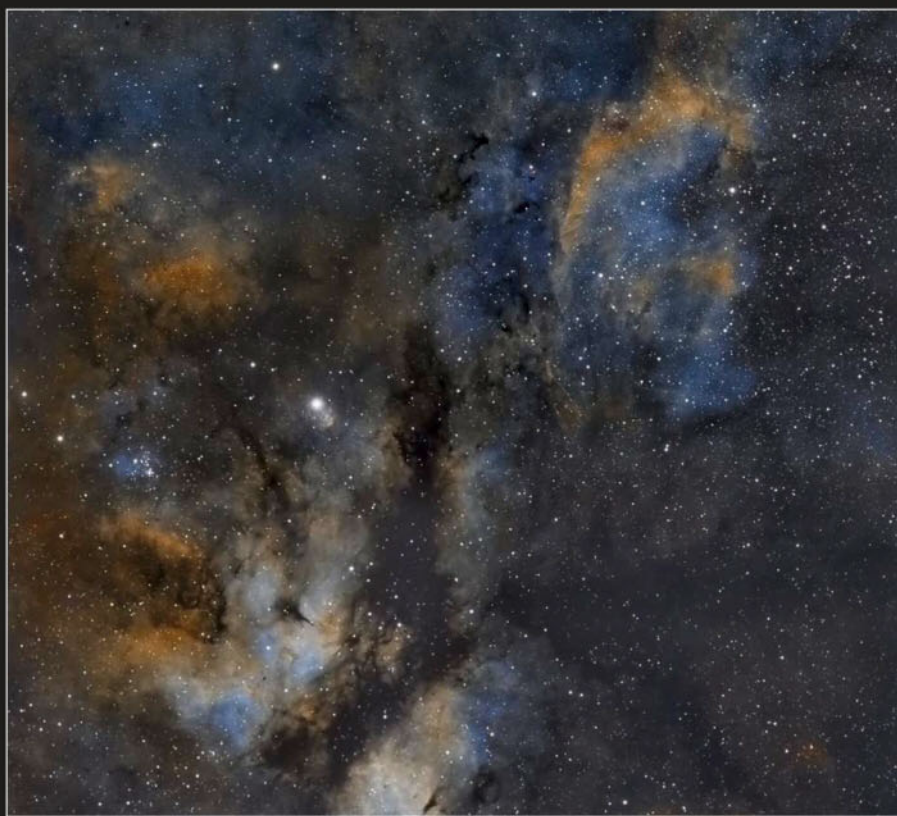


### ▲ Plane transit of the Sun

MARK HOOPER, TEIGNMOUTH, DEVON,  
24 JUNE 2016

**Mark says:** "If I'm honest, this image was pure luck: I had just set up my imaging rig and begun recording when the plane went by!"

**Equipment:** Point Grey Blackfly GigE CCD camera, Orion ED80 apo refractor, Celestron CG-5 equatorial Go-To mount.



### ▲ Sadr region in Cygnus

JUAN IGNACIO JIMENEZ CUESTA, VILLANUEVA DE LA TORRE, SPAIN, 7 JULY 2016

**Juan says:** "The Sadr region contains many clouds of dust and from my location it's available at a good height throughout the night. The sky was quite dusty and generated many halos, which I was able to reduce during processing."

**Equipment:** QHY9 CCD camera, APM TMB 105/650 apo triplet refractor, Sky-Watcher AZ-EQ6 Go-To mount.



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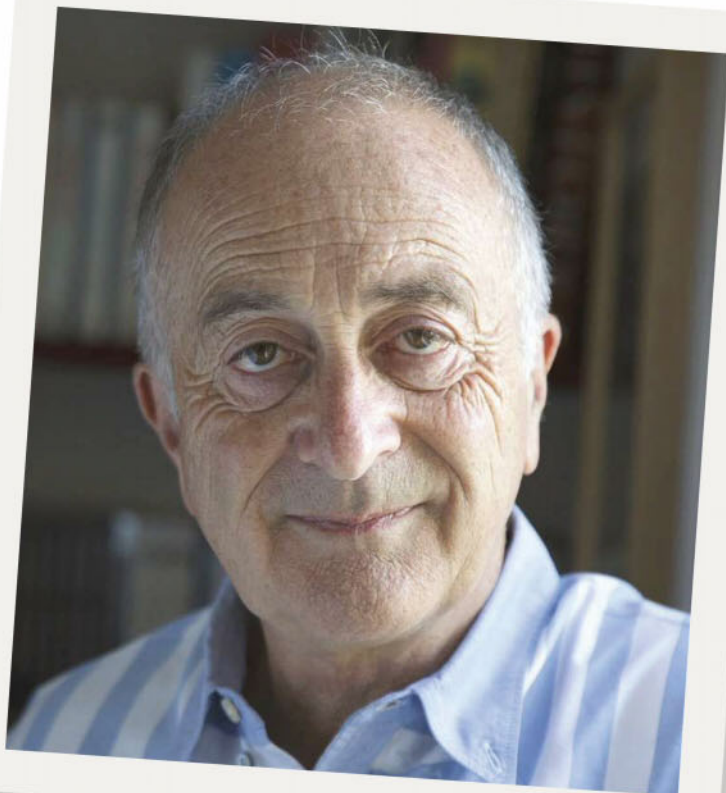
## ENTER TO WIN A PRIZE!

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We've joined forces with Altair Astro UK to offer the winner of next month's *Hotshots* an Altair Astro Planet-Killer 685nm Premium IR Pass Filter with AR Coating, designed to deliver sharper lunar and planetary images with mono CCD or CMOS cameras. [www.altiraastro.com](http://www.altiraastro.com) • 01263 731505

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**“I don’t need  
a cunning  
plan to  
defeat  
dementia.”**

**Sir Tony Robinson  
Alzheimer’s Society Ambassador**

I don’t have the foggiest idea how to kick dementia into the history books. Thankfully I don’t need to, because I can help the people who do.

When dementia took my Mum and Dad I made a pledge that I didn’t want my grandchildren to fear going the same way, so I’m leaving a gift in my Will to Alzheimer’s Society. Without gifts in Wills one in four of Alzheimer’s Society projects would not be funded, affecting both crucial research and vital local services. I’m sure you also want to create a dementia-free future for your family, but without gifts in Wills it could remain a dream for generations to come.

Please join me by leaving a gift in your Will to Alzheimer’s Society.  
For your free Will Guide, please call the charity’s Legacy team on:

**0370 011 0290**

Alternatively for more information visit:

**[alzheimers.org.uk/tonyrobinson](https://alzheimers.org.uk/tonyrobinson)**

Alzheimer’s Society operates in England, Wales and Northern Ireland.  
Registered charity no. 296645.



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against dementia  
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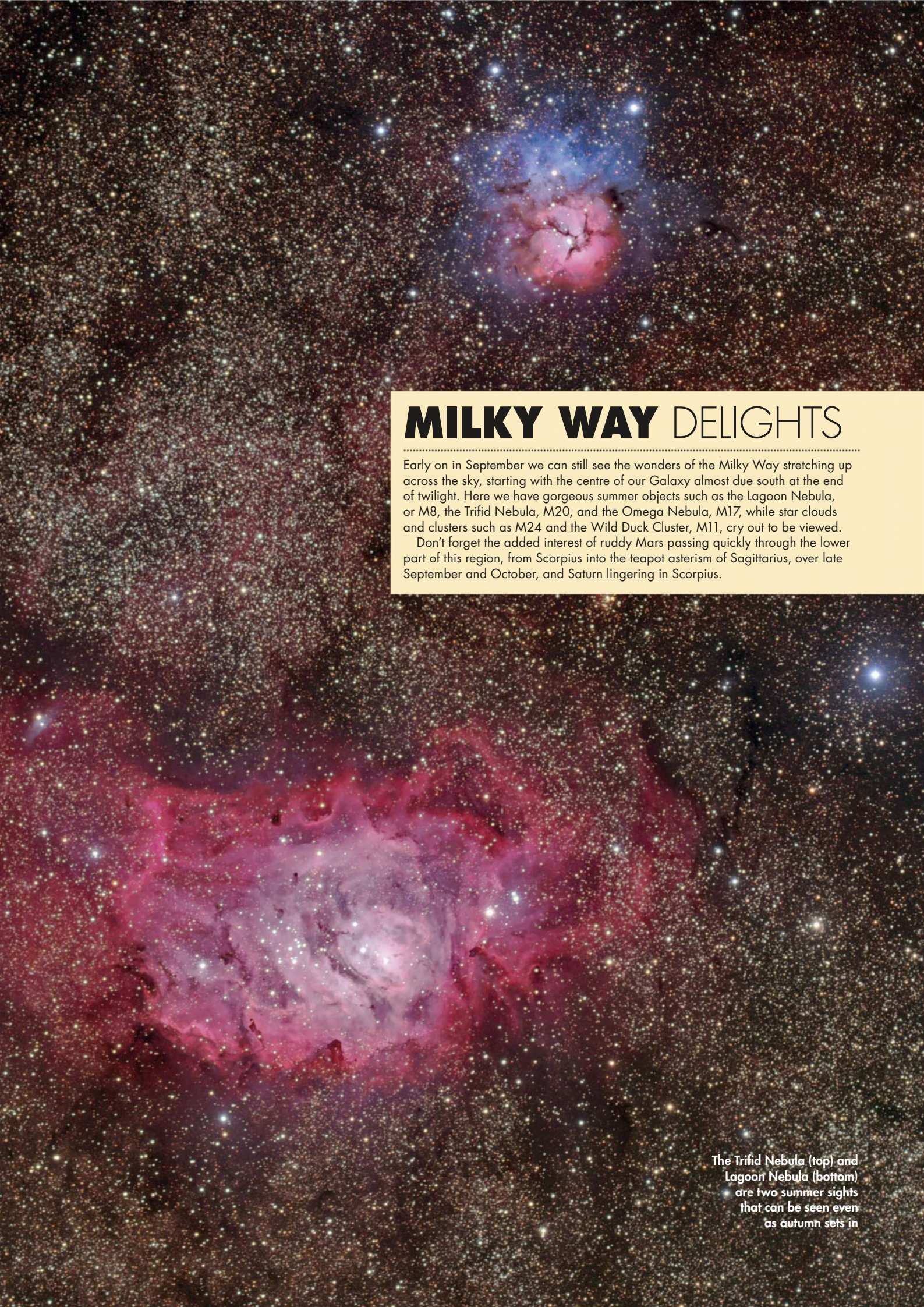


# Long nights beckon

Heralding the return of darkness, **Paul Money** is our guide to the top sights of autumn and how to get your kit ready to see them best. Welcome to the new season of astronomy

**S**eptember is around the corner, the evenings are drawing in, and the promise of long, dark, starry nights beckons us to dust off those binoculars and telescopes. Over the next few months, from September to December, we get a chance to view summer jewels, catch autumn gems at their finest and take the first glimpses of the delights of winter. Thanks to a quirk of Earth's axial tilt, as we approach the autumn equinox in the northern hemisphere the ever-lengthening nights bring summer delights to view earlier in the evenings, set against darker skies. The glories of the Milky Way stay on view giving us a chance to spot nebulae, clusters and the star clouds for that little bit longer. Then, as autumn enters into full swing, we get to look deep into space with galaxies and distant planets on show. So let's get stuck into the treats on offer. ►





## MILKY WAY DELIGHTS

Early on in September we can still see the wonders of the Milky Way stretching up across the sky, starting with the centre of our Galaxy almost due south at the end of twilight. Here we have gorgeous summer objects such as the Lagoon Nebula, or M8, the Trifid Nebula, M20, and the Omega Nebula, M17, while star clouds and clusters such as M24 and the Wild Duck Cluster, M11, cry out to be viewed.

Don't forget the added interest of ruddy Mars passing quickly through the lower part of this region, from Scorpius into the teapot asterism of Sagittarius, over late September and October, and Saturn lingering in Scorpius.

The Trifid Nebula (top) and Lagoon Nebula (bottom) are two summer sights that can be seen even as autumn sets in



# THE LINGERING TRIANGLE

Meanwhile, higher up towards the zenith all three members of the Summer Triangle asterism – comprised of the bright stars Deneb, Vega and Altair – remain on view well into December. Bounded within this triangle is the stunning planetary nebulae the Dumbbell Nebula, M27, and the Ring Nebula, M57. If you enjoy double and multiple stars you won't be disappointed either: Albireo in Cygnus should be on your observing list. Its golden yellow and sky blue components are easily resolvable with a small telescope.

► The distinct 'apple core' of the Dumbbell Nebula, M27 in Vulpecula (top); and the mesmerising pool of the Ring Nebula, M57 in Lyra

Deneb

Vega

Altair

The Summer Triangle stays on show until December, when Altair dips below the horizon

Dark nebulae such as the Cygnus Rift are visible because they block light, leaving a dark chasm in the sky

Cygnus Rift

## INTO THE DARKNESS

Engrossed in the splendours of our Galaxy, it is easy to overlook something that is actually pretty obvious: dark nebulae. Look along the Milky Way towards Cygnus and note the split in the Milky Way. This is called the Cygnus Rift, and is a huge cloud of interstellar dust obscuring our view of the background stars. Cosmic dust like this lies in the plane of our Galaxy and so gives rise to many dark patches that are worth looking out for.



# GET YOUR KIT READY

If you've not used your kit for a while, now's a good time carry out a few checks to make sure that it's all operating in tip-top condition

## 1. CHECK YOUR DOME

If you have an observatory, there is plenty to check on to ensure it runs smoothly. Make sure the dome rotation mechanism is lubricated and the dome itself turns with ease. This also applies to the slit opening. If everything is automated then check motors and power supply are working as desired and are safe to operate. Naturally, over time a dome can become colonised by spiders and so make sure cobwebs are cleared out – unless of course you are a nature lover and they don't cause you any problems.



## 2. SQUEAKY CLEAN OPTICS

Over time your scope's main optics may become dusty or pick up marks from dried dew, so give them a careful clean using a camera air duster or a LensPen optics cleaning tool. For more stubborn marks, consider using optical cleaning fluid and a soft cloth. Newtonian mirrors can be taken out and carefully cleaned using distilled water and a soft fine cloth; if you're doing this it's worth noting the mirror's position in the mirror cell so you can keep it aligned. That neatly brings us to making sure that your main optics are properly aligned to get the best out of them, so have collimating tools handy for the best performance.



## 3. MAINTAIN YOUR MOUNT

It's no good having clean optics if your mount is not behaving itself, so make sure all of its working parts operate smoothly. You may wish to re-grease the drive axis or consider a belt drive modification for better performance. Check your mount is accurately polar aligned

by using the in-built polarscope and aligning on Polaris in the northern hemisphere or Sigma Octantis in the southern hemisphere. If yours is a Go-To mount, make sure you have the latest firmware installed in the handset.



## 4. ACCESSORY REVIEW



It is easy to forget that every system only works as well as its weakest link. Accordingly, check over your

accessories. Are your eyepieces clean and unblemished? Do you have a good set of filters and a filter wheel, and are they clean? Would your setup benefit from a dew heater? Simple things like ensuring the finderscope is aligned with main scope can make all the difference: if you only have a short observing window you don't want to waste it by discovering that your accessories aren't up to scratch.

## 5. ALL CHARGED UP

With today's modern mounts and power-hungry equipment, you have to remain aware of your power needs. Check that any powertanks are fully charged and hold their charge. If not, now is the time to consider replacing them – or buying a better charger which can revive a battery and keep it topped up by trickle charging it. Cameras always need power, so make sure you have enough batteries of the required size. Check your battery recharger's cables for fraying and replace if needed.



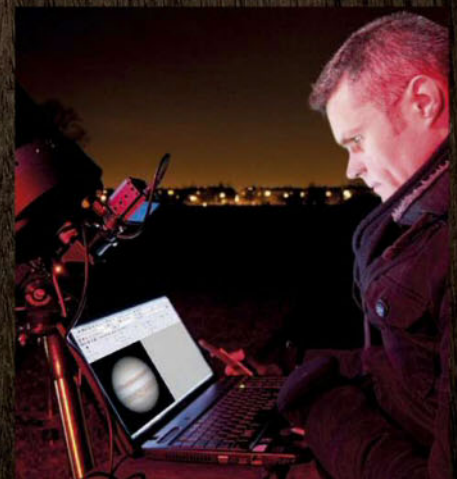
## 6. CAMERA AT THE READY

Today many of us enjoy taking images with a variety of equipment and it's a good idea to check your camera's sensor for cleanliness. Use the in-built cleaning system of a DSLR or carefully have the sensor cleaned at your local photographic shop to rid it of dust and stray hairs. Make sure camera lenses are also clean and free of blemishes. Ideally have them easily at hand in a camera case, stored and clean, and check that any additional cables are not damaged. Check that you have cleared your memory cards and that they still function correctly.



## 7. SOFTWARE SURVEY

Today's dedicated imagers use laptops, so make sure that camera drivers and system software is all up to date with the latest upgrades, especially for in-built graphics cards. Is your capture and imaging software current? Can your laptop handle the high data transfer speeds required of planetary imaging these days, especially if your new camera requires USB 3.0? Have you got a smartphone adaptor for your eyepiece imaging and again is the smartphone up to date with its apps, both image capture and planetarium software?





# GOING GLOBULAR

If you can pry your gaze from the wonders of our own Galaxy, take a look at the multitudes of globular clusters that surround it in a halo. For us this extends from Scorpius up into Serpens, Ophiuchus, Hercules and down into Capricornus, Aquarius and Sagittarius. These incredibly distant objects, several thousand lightyears away, include such gems as M13 and M92 in Hercules, M5 in Serpens, and M22 and M28 in Sagittarius. In small telescopes they often look like little cotton balls.

M92 in Hercules is often overlooked in favour of its famous neighbour M13, but it is every bit as spectacular

## WHAT TO ADD TO YOUR SETUP

Accessories and software to take your observing further this season

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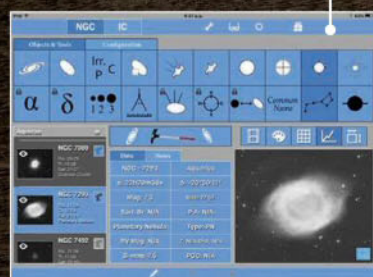


### ASTRO PHOTOGRAPHY TOOL

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[www.astroplace.net](http://www.astroplace.net)

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The Helix Nebula  
in Aquarius looks  
uncannily like an eye

## LURKING IN THE AUTUMN

As we move into October and November, the constellations of Aquarius and Capricornus become better placed over in the south, rich with promising targets. Pick off the final batch of globular clusters such as M30, M2 and M72, along with M15 up in Pegasus. But it is not all balls of stars; seek out the faint but large Helix Nebula and the Saturn Nebula, two planetary nebulae in Aquarius. Meanwhile there are two planetary interlopers coming into view at this time. Neptune lies in Aquarius not too far from Lambda Aquarii, while Uranus is further along the ecliptic in Pisces and becoming better placed to view.

## INTO THE DEEP

From October until the end of the year the final glories of the autumn skies come into view, taking us into the more distant reaches of space. Pegasus has the often overlooked galaxy NGC 7331, while close by lies the more challenging Stephan's Quintet of galaxies. This is prime time for galaxies as Andromeda and Triangulum move into sight. Pick a clear, transparent night, head to a dark sky area and let your eyes become properly dark adapted (it takes about 40 minutes) to stand the best chance of seeing their namesake galaxies, M31 and M33, the farthest objects it is possible to glimpse with the naked eye. Finally, as we approach December, stunning Taurus and mighty Orion come into view for us to feast our eyes on, heralding the start of winter's observing and the joys it promises. **S**



### ABOUT THE WRITER

Paul Money is our reviews editor, an experienced astronomer and an expert on running astronomy outreach events.

NGC 7331 is similar in size and structure to our Galaxy, and is often called the Milky Way's 'twin'; nearby is Stephan's Quintet

NGC 7331

Stephan's Quintet





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19-23 AUGUST 2017

In 2017 we will watch the eclipse from a site in or near Clarksville, Tennessee, as close to the centre-line of the eclipse path as practically possible. Only in the very centre of the eclipse's path do you experience 'totality' and see Baily's beads, the awesome diamond ring effect, prominences and the spectacular solar corona - all with the naked eye.

The weather prospects in Clarksville are excellent and, being close to the point of greatest eclipse, totality will last for a maximum of 2 minutes and 40 seconds.

#### ITINERARY

##### **SATURDAY 19 AUGUST** **Fly Heathrow - Nashville**

Either check in at your regional airport for your connecting flight to Heathrow, or go directly to Heathrow airport for the two-stage flight to Nashville. On arrival in Nashville you will be met by your tour manager and transferred to the hotel for your overnight stay. In the evening there will be a get-together with your fellow passengers and a pre-eclipse presentation by our guest astronomer Dr Lee Sproats.

##### **SUNDAY 20 AUGUST** **Nashville - Clarksville (50 miles)**

After breakfast we embark on a half-day city tour of Nashville including the Country Music Hall of Fame, Printers Alley, Music Row and a drive past the homes of country greats such as Essy Arnold, Minnie Pearl and Hank Williams. In the afternoon we transfer to Clarksville where you will stay for the next two nights.

##### **MONDAY 21 AUGUST** **Clarksville - The Eclipse**

Eclipse-watching today. We will endeavour to take you as close as possible to the centre-line of the eclipse's path in order to get the most dramatic experience of totality.

##### **TUESDAY 22 AUGUST** **Clarksville - Nashville** **- Flight home**

The morning will be at leisure until it is time to transfer to Nashville airport for your overnight two-stage flight back to the UK. If you wish you can extend your stay in the USA under your own steam - just let us know when you make your booking and we can organise your return flight from Nashville for you.

##### **WEDNESDAY 23 AUGUST** **Arrive UK**

Your flight arrives back at Heathrow, with one stop on the way. Passengers with connecting flights to UK regional airports should then transfer to the appropriate terminal for the final leg of the journey home.

#### PRICE INCLUDES

- Return flights from London Heathrow to Nashville (One change. UK regional connections available at a supplement.)
- Three nights' hotel accommodation with breakfast: 1 night at the Hyatt Place Nashville Opryland, 2 nights at the Best Western Plus Atrium Inn & Suites, Clarksville
- Expertise of our guest professional astronomer: Dr Lee Sproats
- Half-day city tour of Nashville

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# LATE SUMMER DEEP-SKY DELIGHTS

If you thought you'd left it too late to observe summer's deep-sky objects, think again. **Vincent S Foster** takes a tour of 10 of the best while there's still time

## INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

If you hunt down these targets, why not considering imaging them for the 2017 Astronomy Photographer of the Year competition? The winners of the 2016 contest will be announced this month.  
[www.rmg.co.uk/astrophoto](http://www.rmg.co.uk/astrophoto)



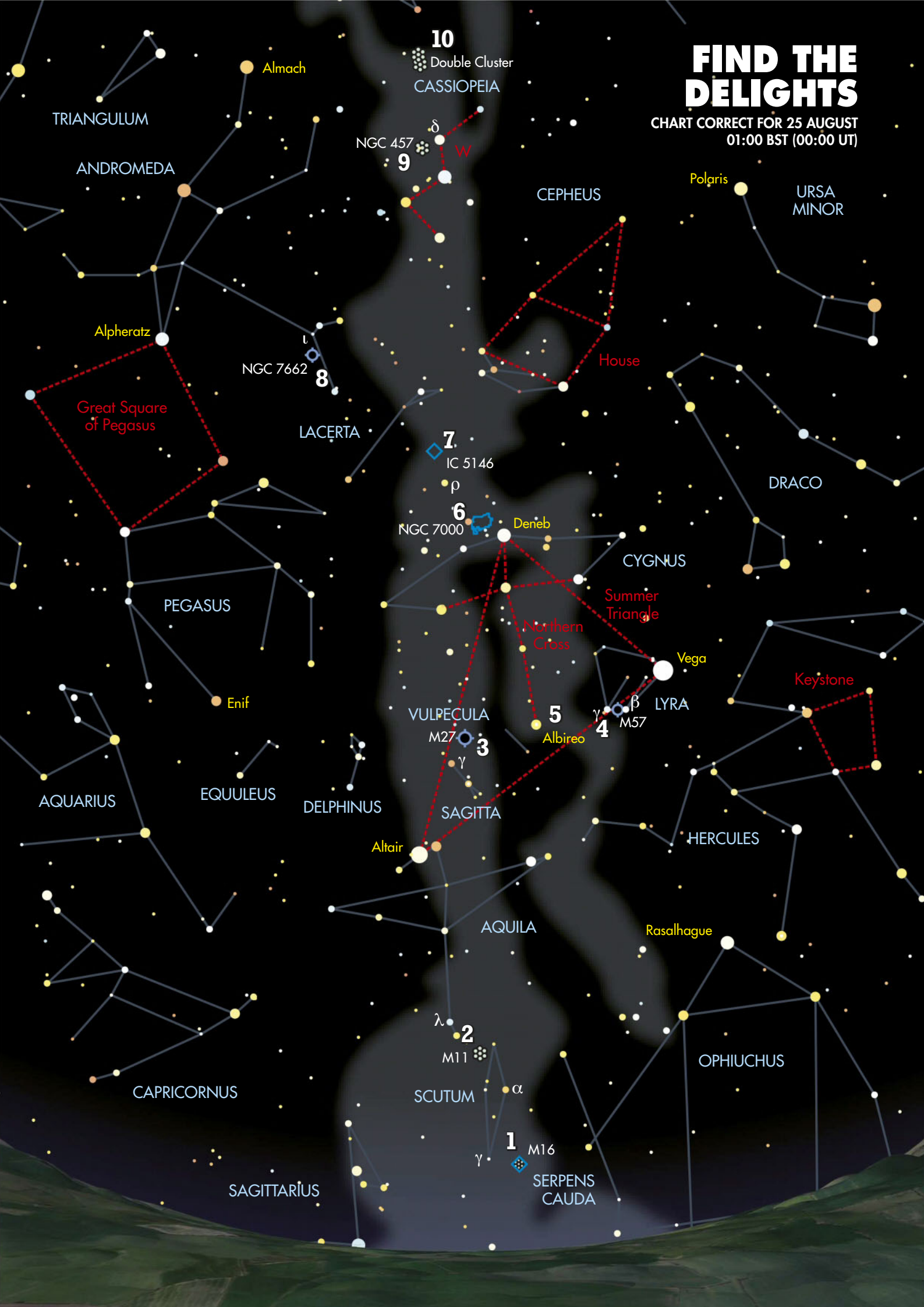
### ABOUT THE WRITER

Vincent S Foster chairs the Hydrogen-Alpha Solar and Bright Nebula observing programmes for the Astronomical League.



# FIND THE DELIGHTS

CHART CORRECT FOR 25 AUGUST  
01:00 BST (00:00 UT)





**T**he Milky Way hasn't vanished with the passing of June and July. This time of the year offers observers a last chance to catch a glimpse of sinking summer favourites and a first look at autumn's upcoming gems. We're going to take a tour that starts in the southwest and works toward the northeast. It's best to view the targets in the order presented here so you don't miss any in the first half of the list, which will disappear

it in the seven o'clock position. In the finderscope, M16 will show as a faint haze in the upper right hand. The nebula is more of a challenge: large aperture telescopes will show it well, but sky conditions are everything when it comes to this one.

Both the cluster and the nebulosity are best seen with low magnifications. A 4-inch telescope reveals about 20 stars in an uneven background of fainter stars and nebulosity; three nebulous concentrations

is 6 inches or less, choose a broadband filter, which often has labels like 'Deep-Sky' or 'Light Pollution Reduction'. A filter labelled OIII is an example of a narrowband filter; these work best on telescopes with large apertures and plenty of light collecting power because they allow far less light through.

Be sure to remove filters when observing the **Wild Duck Cluster (M11) (2)** though: because it comprises only stars, any filter



The Pillars of Creation are just a tiny part of the sprawling Eagle Nebula

below the horizon first. You'll have plenty of time to catch the rest in the months ahead.

Our first stop is the **Eagle Nebula (M16) (1)**, a young open star cluster in Serpens Cauda surrounded by an emission nebula. The nebula is a well-known star-forming region, famous for the Pillars of Creation, imaged by the Hubble Space Telescope in the 1990s.

One of the easiest ways to find M16 is to identify the constellation of Aquila and begin tracing the stars down the Eagle's back to mag. +3.4 Lambda ( $\lambda$ ) Aquilae. When you reach that point, continue to extend the line through to mag. +3.9 Alpha ( $\alpha$ ) Scuti, then southwards towards mag. +4.7 Gamma Scuti. Aim your binoculars or image-erecting finderscope at Gamma ( $\gamma$ ) Scuti and put

M11 is one of the richest open clusters, thought to contain nearly 3,000 stars



can be glimpsed under good observing conditions. Under very good conditions, suggestions of dark obscuring matter can be seen to the north of the cluster. The dark pillars can be seen in large instruments (12 inches or greater).

A nebula filter will help you see it better. These come in two categories: broadband and narrowband. If your scope's aperture

will only dim the object.

M11 is an extremely populous open cluster 6,200 lightyears distant, so rich that it resembles a loose globular cluster. In an 8-inch scope at 50-75x magnification, the cluster's stars are uniform both in distribution and brightness. At 100x magnification, around 150 mag. +11.0 to +14.0 stars can be seen in a

15-arcminute area. At 150x, the cluster stars are distributed in a network of knots and clumps mixed with some meandering dark lanes. Careful scrutiny shows an east-pointing V of brighter cluster members that resembles the formation ducks form when in flight.

Continuing northeast, you will come to the small constellation Vulpecula, the ▶

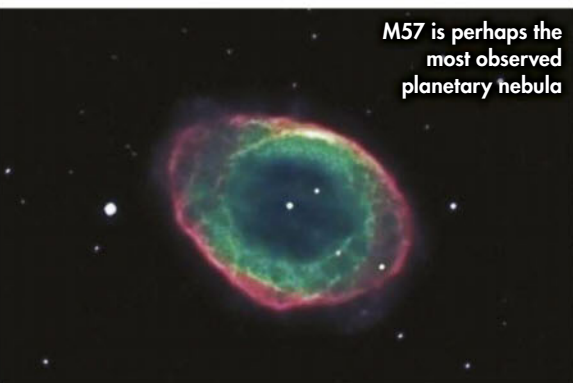




Is M27 the finest planetary nebula in the sky? Have a look and see for yourself

► Fox. There you will find the **Dumbbell Nebula (M27) (3)** which many regard as the finest planetary nebula in the sky. Look for it 3.2° north of mag. +3.5 Gamma (γ) Sagittae. Small telescopes will show it as a large, bright disc pinched in on its east and west sides. The brightest portions appear as wedges to the north and south from the planetary's centre. M27 responds well to high magnification because of its high surface brightness; with powers of 300x and higher and a 10-inch scope, striations crossing the Dumbbell's inner region can be seen.

Next, head to the small but bright constellation of Lyra, the Harp. Nestled midway between 3rd-magnitude Beta (β) and Gamma (γ) Lyrae lies the **Ring Nebula (M57) (4)**. Because it sits high in the northern summer sky, it probably ranks as the sky's most observed planetary nebula. M57 has a beautiful bright oval disc containing a dark, though not completely black, centre.



M57 is perhaps the most observed planetary nebula

The very faint central star is only visible under ideal conditions even in large telescopes. At high powers, wisps of faint nebulosity start to appear and some subtle variations in surface brightness may be seen.

Continue on to the foot of Cygnus, the Swan, where you will find the beautiful

double star **Albireo (Beta Cygni) (5)**. Its gold and blue stars are embedded in the glittering background of the Cygnus Star Cloud. Albireo may well be the most observed of any double star because it is so easy to locate. A single star to the naked eye, with a telescope it readily resolves into gold Albireo A (mag. +3.1), and blue Albireo B (mag. +5.1), separated by

35 arcseconds. It's not known whether the two components are orbiting around each other in a physical binary system.

At the opposite end of Cygnus is the **North America Nebula (NGC 7000) (6)**, a huge emission nebula measuring 3x2.3°. With the unaided eye it can best be seen under dark, transparent skies as a conspicuous Milky Way patch due east of mag. +1.3 Deneb (Alpha Cygni). In 10x50 binoculars, its full extent and entire outline – except for the narrowest part of the Isthmus of

Panama – is visible. To its north the nebula glow merges imperceptibly into a brilliant Milky Way background glow, a stunning region in giant binoculars and rich-field telescopes. Although incredibly large, it is extremely faint, and an OIII filter helps to bring out some detail. The Gulf of Mexico region is fairly conspicuous, flanked by 7th-magnitude stars at the tip of Florida and the southern tip of Texas.

The **Cocoon Nebula (IC 5146) (7)**, lies east of the North America Nebula in a nondescript region of Cygnus. Look 3.7° east-northeast of mag. +4.0 Rho (ρ) Cygni: it overlaps the eastern edge of Barnard 168, one of the northern sky's finest dark nebulae. Its light equals that of a 7th-magnitude star, but the nebula's surface brightness is low.



Blue and gold Albireo is one of easiest double stars to split

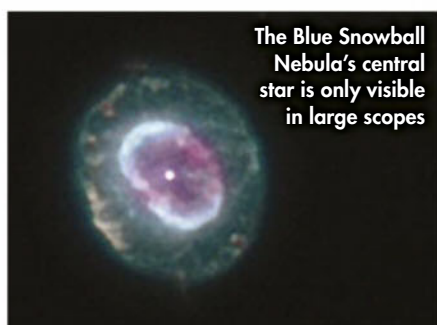
This top of the North America Nebula merges into the Milky Way, but the lower half is incredibly well defined



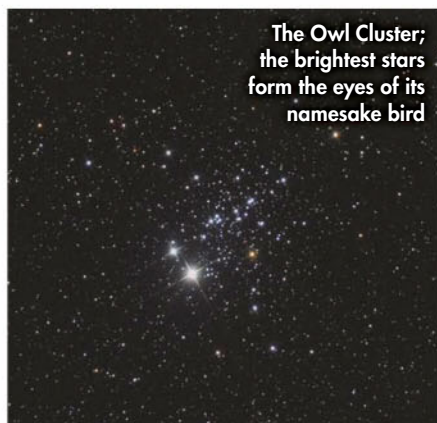




Seeking out the Cocoon Nebula will also give you a glimpse of dark nebula Barnard 168



The Blue Snowball Nebula's central star is only visible in large scopes



The Owl Cluster; the brightest stars form the eyes of its namesake bird

Under dark skies, sharp-eyed observers can pick up this  $1.7 \times 0.2^\circ$  murky lane without optical aids, but it's not easy. A better approach is to use 10x50 binoculars or a telescope/eyepiece combination that gives you a field of view larger than  $1^\circ$ . You can spot the Cocoon Nebula through a 4-inch scope as a circular blue-ish disc. For the best views, use at least an 8-inch scope, around 150x magnification and a nebula filter.

Travel to the constellation of Andromeda and you will find the bluish planetary nebula called the **Blue Snowball (NGC 7662) (8)**. Start at mag. +4.3 Iota (i) Andromedae and head west to variable star 13 Andromedae. Then move  $0.4^\circ$  south-southwest. There

contains 80-100 stars, spread over an area of 16 arcminutes. Two bright stars, mag. +5.0  $\Phi^1$  Cassiopeiae and mag. +7.1  $\Phi^2$  Cassiopeiae, can be imagined as the Owl's blue and yellow eyes.

The final stop is the **Double Cluster (10)** in Perseus. Its components, NGC 884 and NGC 869, are a stunning sight at low power. Each cluster is  $0.5^\circ$  in diameter, but outliers merge into the rich star field that encompasses both groups. NGC 869 is the more compressed of the two and has over 200 members. A relatively star-poor gap cutting northeast-southwest through the cluster separates a looser concentration from the denser southwestern core of the

## “Differences in stellar populations imply that NGC 869 is much younger than NGC 884”

you will find a bright, moderately large and somewhat elongated planetary nebula with a very faint central star. Through an 8-inch scope you will see two lovely bluish-green rings surrounding a slightly darker centre. Magnifications of 50-100x works best.

The **Owl Cluster (NGC 457) (9)** can be found in Cassiopeia. An 8-inch scope at 75x shows a stick figure with its arms spread wide as if to welcome you. It is detached from the background and finding it is easy: from mag. +2.7 Delta ( $\delta$ ) Cassiopeiae look  $2^\circ$  south-southwest. At mag. +6.4, NGC 457 is one of the brightest open clusters in Cassiopeia. It

bright stars. To the east, NGC 884 is larger – but not as bright nor as concentrated as its neighbour. Its 175 stars range from mag. +6.5 to mag. +14.0. Three red supergiants provide a nice colour contrast. Differences in their stellar populations imply that NGC 869 is significantly younger than NGC 884: six million as opposed to 14 million years old.

This list of 10 late summer celestial treasures will get you going. Hundreds more await you along the Milky Way. That's more than enough to keep you observing through autumn! **S**



You need a wide field of view to see the members of the Double Cluster together

CHRISTOPH KAUTSIS/CCDGUIDE.COM X 2, SEBASTIAN VOLTMER/CCDGUIDE.COM, JOHANNES SCHEDLER/CCDGUIDE.COM X 2, MICHAEL BREITE/STEFAN HEUTZ/ WOLFGANG RIES/CCDGUIDE.COM, MARKUS BLAUENSTEINER/CCDGUIDE.COM, ISTOCK



# The radio GIANT

A huge telescope in China is set to unlock the secrets of the radio Universe, as **Elizabeth Pearson** discovers

**M**easuring half a kilometre in diameter, the world's largest single dish telescope is ready to turn its ear to the Universe. Over the past decade, the Five Hundred Metre Aperture Spherical Telescope, or FAST, has been taking shape

in southern China's Guizhou province. From this September it will finally begin its mission and start to listen for radio waves coming from the depths of space.

The 500m-wide dish has a surface area of 196,000 square metres, making it the largest radio telescope ever built.

The previous record holder, the Arecibo Telescope in Puerto Rico, measures a mere 305m across, creating a surface area of 73,000 square metres. The two scopes share much in their designs, but the size of FAST will dwarf the capabilities of its predecessor.



At 500m in diameter, FAST is nearly 200m larger than its closest rival





▲ A technician fits the triangular panels, each of which can be moved individually to alter the shape of the dish and reorientate the scope



▲ Suspended 150m above FAST's dish, this central receiver cabin will collect all of the telescope's data

"FAST has an amazingly large collecting area, meaning it can detect faint radiation from anywhere in the Universe," says Douglas Bock, the acting director of the Commonwealth Scientific and Investigation Research Organisation (CSIRO), which is building FAST's receiver. This extra light-gathering power makes FAST twice as sensitive to radio waves as Arecibo, allowing it to see into the depths of the Universe. But to take full advantage of that sensitivity a radio quiet zone of 5km has been set up around the scope: entire villages have had to be resettled and mobile phones are banned to ensure its 70MHz to 3GHz frequency range is kept clear.

## No traditional telescope

Another advantage FAST has over Arecibo is that it can scan across the sky instead of being fixed in position pointing at the zenith. But it doesn't slew around the sky like a traditional telescope – moving such a vast structure would be impossible. Instead, the telescope moves by warping the dish.

To achieve this, FAST is comprised of 4,450 triangular panels arranged to form a spherical bowl. By pulling on various points of the dish with cables, it's possible to pull it into the shape of a parabola. This not only removes the effects of spherical aberration, where signals from different parts of the dish don't perfectly align to a singular focus point, but by changing the position of the parabola's centre the telescope's view steers across the sky.

The central receiver, which is suspended above the centre of the huge bowl, can swing in its cradle to point at the correct point on the dish, meaning that FAST can 'move' up to 60° away from the zenith. Once in position, the receiver's

19-beam design means that it can detect from several parts of the dish at once. Combining this with its record-breaking size, FAST can survey huge areas five to 10 times faster than its predecessors. This means that the scope will be able to go deeper into the radio Universe than any have gone before.

With such a powerful instrument up for grabs, promising such a wealth of new data, several major projects have already been lined up for the scope. They include a full survey of our Galaxy's neutral hydrogen.

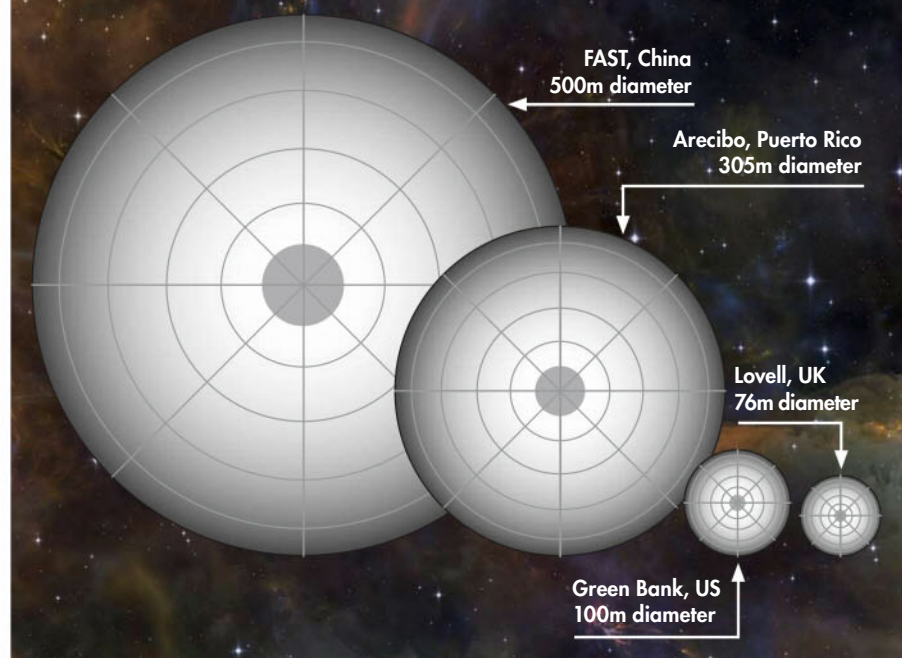
"Hydrogen is the most abundant element in the Universe. So it's important

to make a very sensitive survey of the gas in our Galaxy," says Bock. The gas is the main ingredient in star formation, and is found throughout our Galaxy, but previous surveys have only covered the galactic disc. FAST will be able to search above the disc for clouds of hydrogen, giving a wider picture of star formation in our corner of the Universe.

"Another goal of FAST is to detect tens of thousands of other galaxies in neutral hydrogen," Bock continues. "It will be able to detect galaxies six billion lightyears away. That's half the age of the Universe that those radio signals could have been travelling." ▶

## HOW DOES FAST MEASURE UP?

The most famous single dish radio telescopes compared



© XINHUA/ALAMY STOCK PHOTO X 3



# CONSTRUCTING A COLOSSUS

Many of FAST's biggest challenges came long before first light

Building a goliath such as FAST is far from simple, and the team behind its creation had dozens of issues to overcome before it could be finished. The first was trying to find a suitable site. After years of searching remote locations, away from the background radio pollution of modern civilisation, the team found the perfect spot – a limestone basin not only sturdy enough to hold the weight of the telescope, but naturally shaped to accommodate the structure.

To hold the dish in place requires a ring of 50 pillars. Suspended from this is a net made from thousands of cables supporting more than 4,450 aluminium panels. Each segment is perforated with holes, partly to cut down on weight and partly to let sunlight through to the ground below, allowing plants to grow. Without vegetation, wind and rain would erode the soil, putting the entire structure at

risk of collapse. The size of the 30-tonne central receiver also proved to be quite a challenge.

"The receiver has got to be very cold inside, just a few degrees above absolute zero," says Douglas Bock, acting director of CSIRO. "And when you try to cool down very large structures and keep them cold there are a lot of complications. For starters we had to build a bigger lab."

With such a large, but sensitive, instrument there is a huge amount of data being produced. Transfer speeds of up to 100GB per second are needed to keep up with the stream, which is broadcast to a dedicated data handling facility. There will be so much information coming in that a new supercomputer has been built to process it all. Capable of making over one thousand trillion calculations a second, it will be the fastest astronomical computer ever created.

► It's hoped that this will help uncover 'dark galaxies' – clumps of hydrogen held together with dark matter that have the mass of a dwarf galaxy, but lack stars. Current theories about the nature of the Universe predict that we should see many more small galaxies than we observe; dark galaxies may help to close the gap between theory and reality.

The increased level of sensitivity should also uncover many new pulsars – highly magnetised neutron stars that emit pulses of radio waves. Only around 2,500 are currently known and most of these are on the very cusp of what is observable.

With FAST's extra power, it should be able to add another 7,000 to this number. Among them will be some of the rarer pulsars that have been hypothesised but not observed such as binaries, doubles, and those orbited by planets. It should even be able to spy those that lie in galaxies other than our own.

"Finally, FAST will be able to look for radio signals from exoplanets," says Bock. "Partly in a search for non-natural signals signifying extraterrestrial intelligence, but also for the radio signatures from the planets themselves, the same way that we can detect the magnetic field of Jupiter."

The telescope's final panel was lowered into place on 3 July, finishing off what will be one of astronomy's grandest achievements. After years of planning and preparing, FAST is finally ready to give us unprecedented views of the radio Universe and open up entire new realms of the cosmos. **S**

FAST will also be used to search for exoplanets by looking for their radio signals



## ABOUT THE WRITER

Dr Elizabeth Pearson is BBC Sky at Night Magazine's news editor. She gained her PhD in extragalactic astronomy at Cardiff University.





**Written by  
Pete Lawrence**

Pete Lawrence is an expert astronomer and astrophotographer with a particular interest in digital imaging. As well as writing *The Sky Guide*, he appears on *The Sky at Night* each month on BBC Four.

PETE LAWRENCE

# The Sky Guide September

The full Moon that falls closest to the northern hemisphere's autumn equinox is known as the Harvest Moon. This year, the Harvest Moon occurs on 16 September. It rises at around 19:30 BST, at which time the full Moon will be undergoing a weak penumbral eclipse.



**PLUS**  
Stephen Tonkin's  
**BINOCULAR TOUR**  
Turn to page 58 for six  
of this month's best  
binocular sights



# Highlights

Your guide to the night sky this month



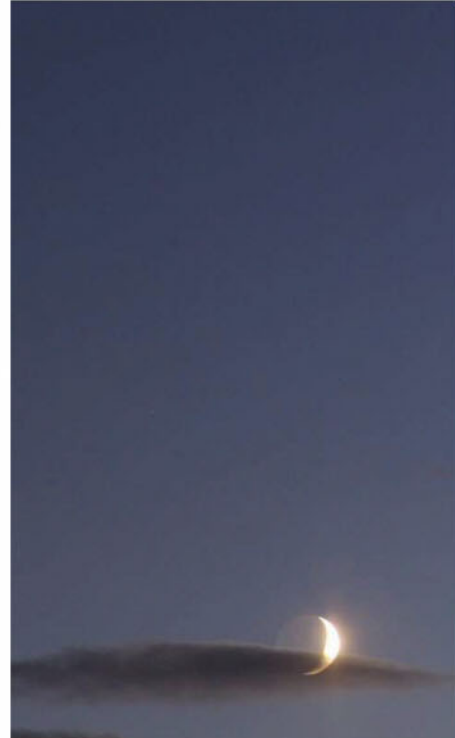
This icon indicates a good photo opportunity

**1 THURSDAY ▶**  
 Mag. +0.9 Saturn, -0.3 Mars and +1.0 Antares (Alpha (α) Scorpii) form an equilateral triangle, visible low down in the south-southwest from around 21:00 BST (20:00 UT) until they set. Saturn will be 6° from Mars and Antares at this time.



**2 FRIDAY ▶**  
 A waxing crescent Moon (1% lit) is 1.75° west of mag. -1.5 Jupiter this evening. Look for the pair low above the western horizon 25 minutes after sunset. Also, look out for Venus, which is 6° east of Jupiter.

Neptune reaches opposition today.



**8 ◀ THURSDAY**  
 Saturn appears 3° south of the waxing crescent Moon (43% lit). Look for them low in the southwest at around 21:45 BST (20:45 UT).

**9 FRIDAY**  
 Mars appears 7° below the first quarter Moon as the sky begins to darken. Look for planet and Moon low in the south-southwest.

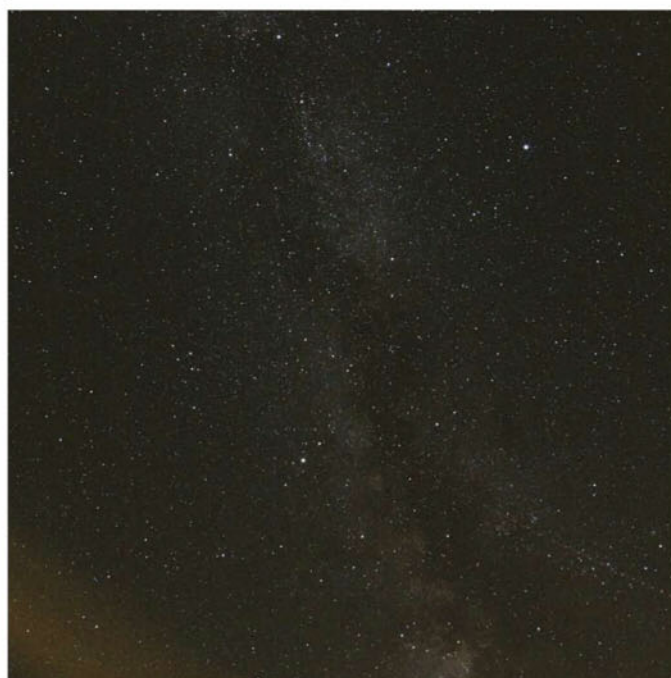
**15 THURSDAY**  
 Neptune reappears from behind the Moon's disc at 21:00 BST (20:00 UT). The planet was covered by the Moon in twilight about an hour earlier at 20:04 BST (19:04 UT). See page 51.

**19 MONDAY**  
 Minor planet Vesta is in Gemini. This evening it is mag. +8.4 and passes 40 arcminutes to the south of the Eskimo Nebula, NGC 2392.

**20 TUESDAY**  
 The waning gibbous Moon (85% lit) occults mag. +4.3 star Mu (μ) Ceti just after 01:00 BST (00:00 UT). Those in the right part of the southeast will see the star blink on and off as the edge of the Moon grazes past it.

**21 WEDNESDAY**  
 The Moon is only 24 arcminutes – slightly less than one apparent diameter – from orange star Aldebaran, the brightest star in Taurus. Closest approach is around 22:45 BST (21:45 UT).

**22 THURSDAY ▶**  
 The Sun crosses the celestial equator at 15:21 BST (14:21 UT) today, marking an instant in time known as the northern hemisphere's autumn equinox.

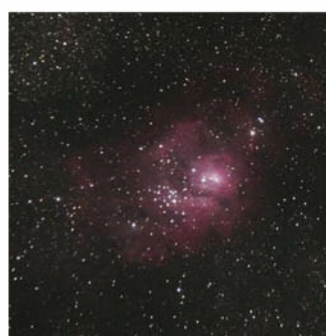


**23 ◀ FRIDAY**  
 The Moon is out of the way now so why not point your telescope at the heart of Cygnus and follow our deep-sky tour of some of the wonderful objects on view. See page 56.



**28 WEDNESDAY ▶**  
 Mars lies 1.5° south of the Lagoon Nebula in Sagittarius, M8. Binoculars will show them both; look low in the south-southwest at 21:00 BST (20:00 UT). Mars is 6° above the horizon.

Mercury reaches greatest western elongation, separated from the Sun by 18° and visible in the morning sky.





## What the team will be observing in September



**Pete Lawrence** "I can't resist a challenge and there are two great ones this month. On the 15th, Neptune will reappear from a lunar occultation that started in twilight. Then on the 30th the Moon will occult Jupiter."



**Steve Marsh** "It's all about Andromeda for me this month. M31 will be well above the light pollution haze and wobbly seeing close to the horizon so I'll be trying to capture both narrow and wide-field shots of it."



**Paul Money** "Mercury races into the morning twilight from the third week of September and on the 29th the crescent Moon will be close by for a great photo opportunity."

**3 SATURDAY**  
 Venus will appear to be 15 arcminutes from the southern limb of the waxing crescent Moon (4% lit) at 10:58 BST (09:58 UT). It will daylight at this time, but they will still be visible, 20° up in the east-southeast. Just after sunset, they will appear separated by a little under 3.5°.

**16 FRIDAY**  
 Tonight's full Moon rises while inside the Earth's penumbral shadow. This penumbral eclipse continues with the weak shadow finally leaving the Moon's disc at 21:55 BST (20:55 UT). Penumbral eclipses are tricky to see, but may be recorded using a camera. See page 50.



**26 MONDAY**  
 The fabulous Beehive Cluster in Cancer, M44, is only 5° north of this morning's waning crescent Moon (21% lit). View both with a pair of binoculars from 05:00 BST (04:00 UT).

**27 TUESDAY**  
 The magnificent Andromeda Galaxy, M31, now reaches its highest point in the sky around 01:30 BST (00:30 UT). With the Moon out of the way, this a great time to get an early view or image of this wonderful galaxy.

**29 THURSDAY**  
 Mag. -0.4 Mercury is 1° from the Moon's northern limb at 10:00 BST (09:00 UT), and this should be visible in daylight. The Moon's waning crescent (2% lit) is roughly one-third the way up the sky in the southeast. Take care if sweeping with binoculars as the Sun is not too far away.

**30 FRIDAY**  
 The waning crescent Moon (<1% lit) will occult Jupiter in broad daylight. This is a challenging observation as both objects will be a little under 4° from the Sun. See page 51.

## Need to know

The terms and symbols used in *The Sky Guide*

### UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

### RA (RIGHT ASCENSION) AND DEC. (DECLINATION)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object lies on the celestial 'globe'.

### HOW TO TELL WHAT EQUIPMENT YOU'LL NEED



#### NAKED EYE

Allow 20 minutes for your eyes to become dark-adapted



#### BINOCULARS

10x50 recommended



#### PHOTO OPPORTUNITY

Use a CCD, planetary camera or standard DSLR



#### SMALL/MEDIUM SCOPE

Reflector/SCT under 6 inches, refractor under 4 inches



#### LARGE SCOPE

Reflector/SCT over 6 inches, refractor over 4 inches



## Getting started in astronomy

If you're new to astronomy, you'll find two essential reads on our website. Visit [http://bit.ly/10\\_Lessons](http://bit.ly/10_Lessons) for our 10-step guide to getting started and [http://bit.ly/First\\_Tel](http://bit.ly/First_Tel) for advice on choosing a scope.



# DON'T MISS...

## 3 top sights

### 📷 Harvest Moon eclipse

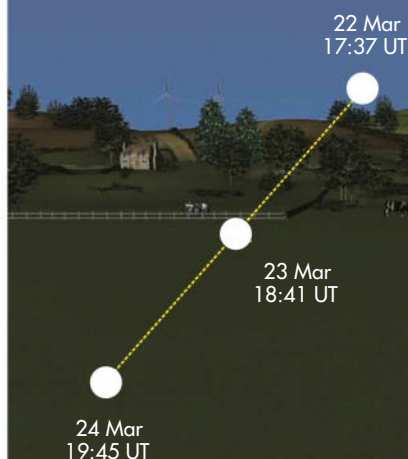
**WHEN:** 16 September, from moonrise (19:30 BST/18:30 UT from the centre of the UK)



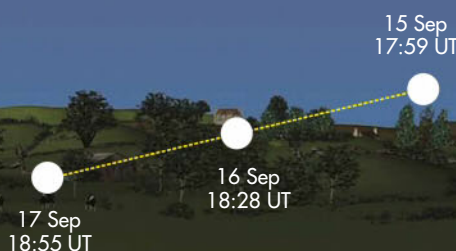
#### NEED TO KNOW

An object's brightness is given by its magnitude. The lower the number, the brighter the object: with the naked eye you can see down to mag. +6.0.

Moonrise times close to the northern hemisphere's 2016 spring equinox back in March varied by approximately 55 minutes



Moonrise times close to the northern hemisphere's autumn equinox this September will vary by approximately 30 minutes



variation between moonrise times for the fuller phases of the Moon is minimised. The difference is normally around 50 minutes, but close to the September equinox, it reduces to approximately 30 minutes.

The full Moon that occurs closest to the September equinox is known as the Harvest Moon. This title comes about because of the decreased difference in moonrise times in the days around full Moon. Rising at similar times, the bright Moon was seen to light the way for the harvest.

This year, the rising Harvest Moon on 16 September will be eclipsed by a weak part of the Earth's shadow known as the penumbra. The eclipse starts when the Moon is below the horizon at 17:54 BST (16:54 UT) and concludes at 21:54 BST (20:54 UT). Maximum eclipse is at 19:54 BST (18:54 UT) when the Moon is low in the east. A penumbral eclipse tends

not to be that visually exciting as the dimming of the Moon is very hard to see with just your eyes. However, cameras may be able to detect a darkening close to the northern limb, the portion of the Moon which will be closest to the darker umbral shadow.

◀ A penumbraally eclipsed full Moon showing a subtle darkening towards the upper-left edge

**THE MOMENT** THE centre of the Sun appears to cross the celestial equator is an instant in time known as an equinox. The Sun's path around the sky is a great circle; a circle around a sphere which has its centre co-incident with the sphere's centre. This particular great circle is known as the ecliptic.

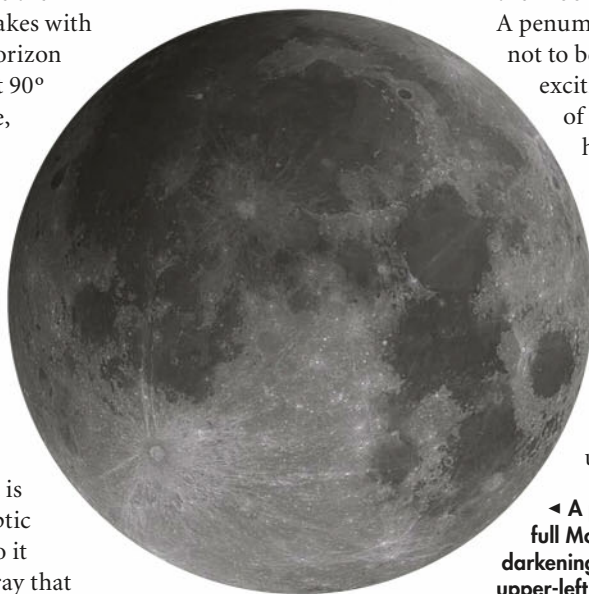
The ecliptic is inclined to the celestial equator, the projection of the Earth's equator onto the celestial sphere. The inclination angle of 23.5° is known as the obliquity of the ecliptic. Think of two hoops arranged so their centres are in the same place but with one of the hoops inclined to the other by 23.5°.

From a static location on Earth, the position of the

celestial equator appears fixed. The tilted ecliptic on the other hand, appears to rotate around us once every day. While the angle the celestial equator makes with the east and west horizon remains constant at 90° minus your latitude, that of the ecliptic varies. At sunset around the September equinox, the ecliptic makes a shallow angle with the eastern horizon as seen from mid-northern latitudes.

The Moon's orbit is inclined to the ecliptic by a little over 5°, so it never appears to stray that

far from it. The shallow horizon angle of the ecliptic in the east at sunset during late September means the





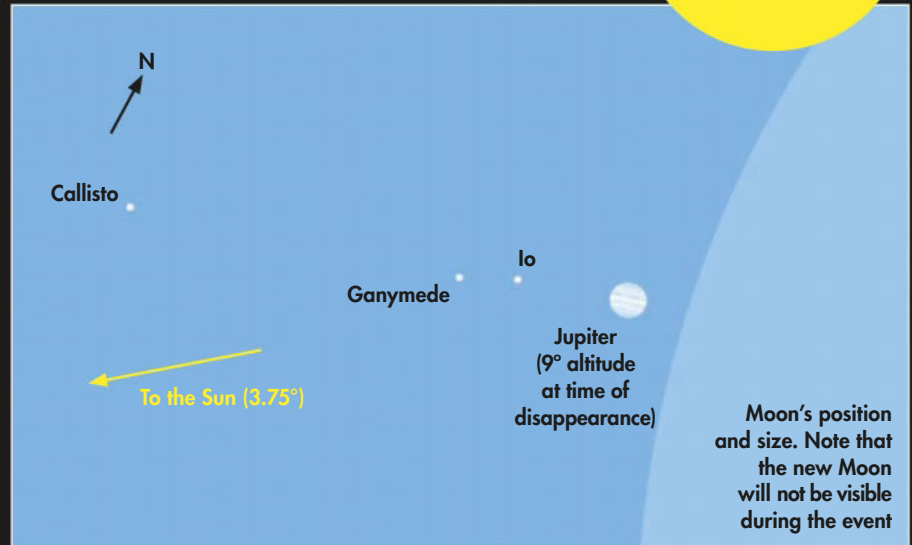
## ☼ Daylight occultation of Jupiter

**WHEN:** 30 September, locate Jupiter from 17:15 BST (16:15 UT)

SOME EVENTS IN astronomy are easy to see and some are hard – and the 30 September daylight lunar occultation of Jupiter can definitely be described as the latter. Two factors contribute to the challenging nature of this occultation. First, both the virtually new Moon and mag.  $-1.5$  Jupiter will be difficult to locate in daylight. Then there's the fact that they are just  $3.75^\circ$  from the Sun when Jupiter first slips behind the Moon. This is dangerously close and should only be attempted if you really know what you're doing.

There's an easier warm up event on 3 September when the waxing crescent Moon (4% lit) passes  $0.5^\circ$  north of mag.  $-3.8$  Venus. Closest approach occurs around 10:50 BST (09:50 UT), again in daylight. Both objects will be separated from the Sun by a more comfortable  $24^\circ$  at this time.

We don't recommend looking at the 30 September event visually. It's better suited for imaging with a high frame rate camera. The best way to find Jupiter is to fit a white light solar filter to the front of your telescope, centre on the



Sun and focus accurately. If your mount has Go-To capability, sync on the Sun's position and simply slew to Jupiter. Alternatively, setting circles can be used to offset from the Sun's position to Jupiter. Take care and check that sunlight is not passing down the tube of your telescope as you remove the solar filter.

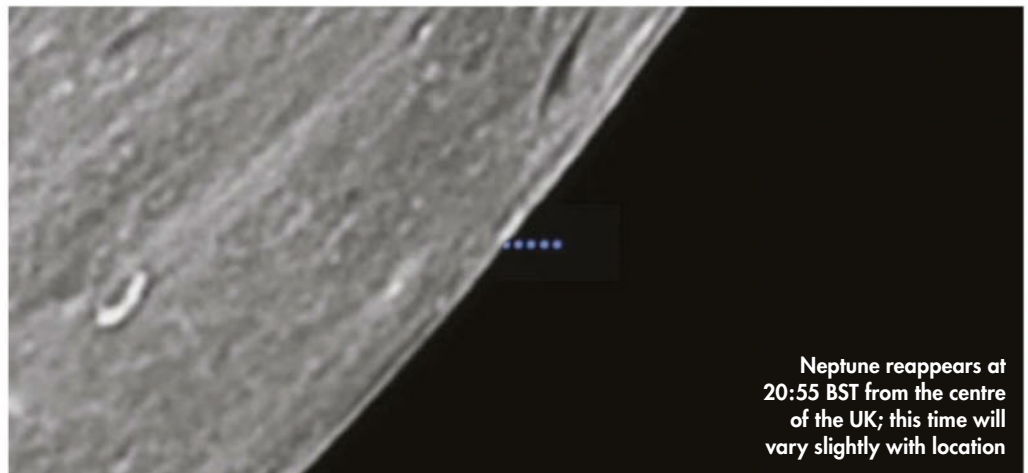
A red or infrared filter fitted to a monochrome camera will darken the

background sky. Keep the frame rate high while adjusting gain and exposure to brighten the sky close to saturation to locate weak Jupiter. If you do manage to locate it, the Moon's disc will occult the planet at 17:47 BST (16:47 UT), from the centre of the UK. Times vary slightly with location. Reappearance occurs after moonset.

## 🔭👁️ Neptune reappears

**WHEN:** 15 September, observe from 20:40 BST (19:40 UT)

THERE'S ANOTHER OCCULTATION of a planet by the Moon this month, and like that of Jupiter described above, this one also has some challenges. Here, it's the reappearance part of the occultation that is visible. At 20:55 BST (19:55 UT) Neptune reappears from behind the bright limb of an almost full Moon (98% lit). The event takes place in darkening evening twilight and both objects will have a respectable altitude of around  $15^\circ$ .



A telescope or binoculars will be required to see mag.  $+7.8$  Neptune as it makes its reappearance. A high power setup pointed at the right part of the Moon's limb should show Neptune's bluish disc next to it just after reappearance. As luck would

have it, as Neptune reappears, a marginally brighter star, mag.  $+7.3$  TYC5812-1021-1, will disappear on the opposite edge of the Moon's disc a couple of minutes later. This star then reappears at 21:22 BST (20:22 UT), so despite missing the disappearance of

Neptune, which occurs in daylight, it is at least possible to see a full occultation of this star. All times are for the centre of the UK and will vary slightly with location. For further details including how to image this event, turn to page 60.



# The planets

## PICK OF THE MONTH

### NEPTUNE

**BEST TIME TO SEE:** 2 September, 01:15 BST (00:15 UT)

**ALTITUDE:** 28°

**LOCATION:** Aquarius

**DIRECTION:** South

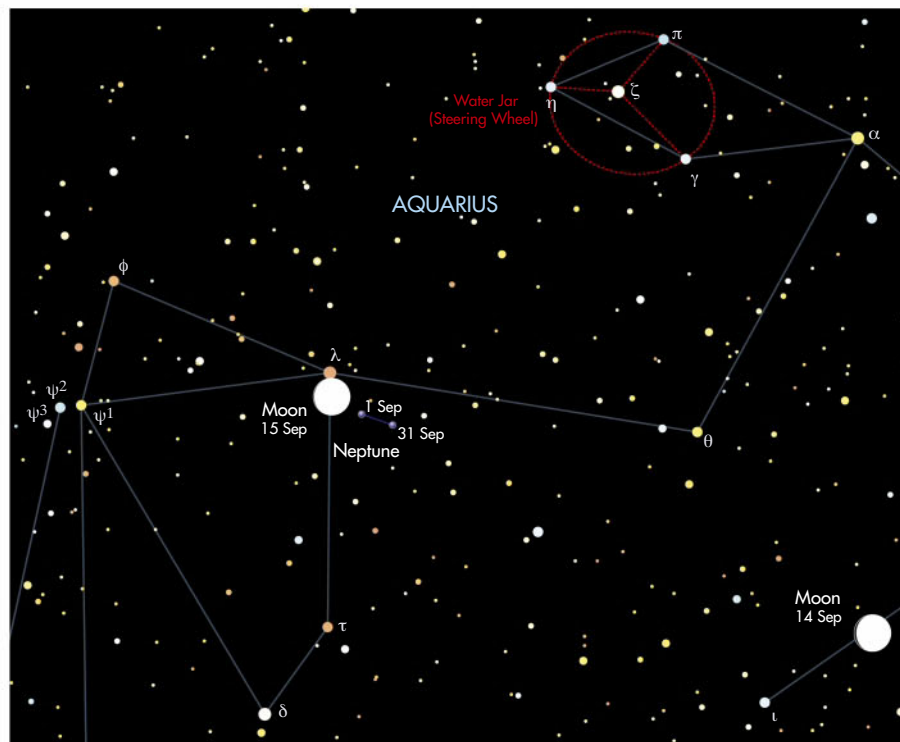
**FEATURES:** Colour, possible atmospheric features with large telescopes, the moon Triton

**EQUIPMENT:** Binoculars, 3-inch scope

NEPTUNE IS AT opposition on 2 September, this being the point when it is positioned opposite the Sun in the sky. It will be visible all night long, making this a great time to look for the planet. Opposition reduces the distance between Earth and a planet to a minimum for the current period of observation.

This has the effect of increasing a planet's apparent brightness and size. However, the effects diminish with distance. Mars at opposition changes appearance dramatically, while distant Neptune hardly looks any different from other occasions.

Binoculars are required to see the



▲ Neptune remains near mag. +3.7 Lambda Aquarii, and is occulted by the Moon on the 15th

planet as it's too dim at mag. +7.8 to be seen with the naked eye. Binoculars will show it looking like a dim white star, while a telescope at

around 150x magnification will reveal its tiny, 2.3-arcsecond disc.

This has a definite blue colour to it.

High-resolution imaging setups combined with a large telescope may reveal atmospheric features, but typically, Neptune is too far away to give up many of its secrets. A long

pass (red end of the spectrum) filter will typically record the most detail on this distant world.

Neptune's largest moon is Triton, which shines at mag. +13.5. In theory, an 8-inch scope should allow you to see it, but a 10-inch instrument at around 200-250x is will make finding it easier. This is the only large moon in the Solar System to have a backward, or retrograde, orbit around its planet. It's also surprisingly easy to image considering the distance of the Neptunian system.

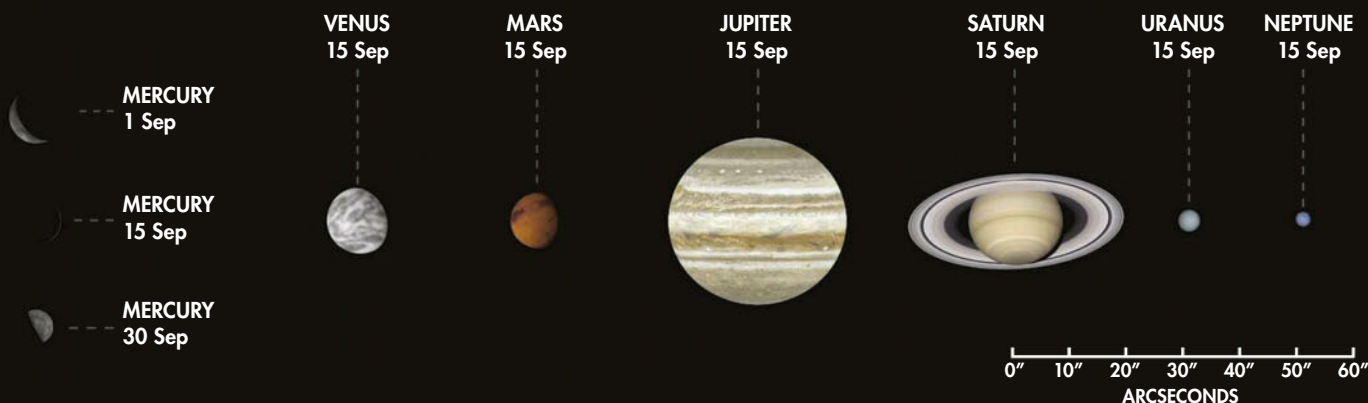
Neptune is currently in the constellation of Aquarius, close to the mag. +3.7 star Lambda (λ) Aquarii. From the centre of the UK it manages to achieve a peak altitude of around 18°.



▲ Large scopes can reveal Triton, the largest of Neptune's moons

## THE PLANETS IN SEPTEMBER

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





## URANUS

### BEST TIME TO SEE:

30 September, 02:00 BST  
(01:00 UT)

**ALTITUDE:** 45°

**LOCATION:** Pisces

**DIRECTION:** South

Uranus is heading towards opposition, which occurs on 15 October. This means that from now until mid-November, the planet will be at its best for the year. This month Uranus shines away at mag. +5.7 and can be located in Pisces, 2.5° north of mag. +4.8 Mu (μ) Piscium. A small telescope at 100-150x magnification will show its tiny 3.7-arcsecond disc. What is most striking is Uranus's colour – it appears a beautiful green.

## MERCURY

### BEST TIME TO SEE:

29 September, 06:00 BST  
(05:00 UT)

**ALTITUDE:** 5° (low)

**LOCATION:** Leo

**DIRECTION:** East

Mercury spends the first half of September in the evening sky setting either with or slightly before the Sun. Consequently it isn't visible with the naked eye. It lines up with the Sun on the nearside of its orbit (inferior conjunction) on the 13th, after which it becomes a morning object, reaching greatest western elongation on the 28th. Mercury is brightest and easiest to see at the end of September, but the presence of a waning crescent Moon (2% lit) 2° from Mercury on 29 September gives this morning the edge if you're trying to spot it. On the morning of the 29th, it'll be 33 arcminutes from mag. +4.0 Sigma (σ) Leonis.

## VENUS

**BEST TIME TO SEE:** 20 minutes after sunset

**ALTITUDE:** 3.5° (low)

**LOCATION:** Libra

**DIRECTION:** Southwest

Venus is an evening object, but not particularly well placed,

setting soon after the Sun. On the 3rd, the waxing crescent Moon (5% lit) is 3° from the planet in the evening twilight.

## MARS

### BEST TIME TO SEE:

1 September, 21:00 BST  
(20:00 UT)

**ALTITUDE:** 8.5° (low)

**LOCATION:** Scorpius

**DIRECTION:** South-southwest

Mars is 'treading celestial water' this month. By this we mean that as the stars drift naturally westward at the same time each passing day, Mars's apparent eastward motion is able to compensate for this. Consequently, Mars appears to stay in the same general location relative to the horizon when viewed at the same time on subsequent evenings. The planet appears largest at the start of the month, its apparent diameter dropping from 10.5 arcseconds on 1 September to 8.5 arcseconds by the 30th. It also dims slightly from mag. -0.3 to +0.1 during the month.

## SATURN

### BEST TIME TO SEE:

1 September, 21:00 BST  
(20:00 UT)

**ALTITUDE:** 12°

**LOCATION:** Ophiuchus

**DIRECTION:** South-southwest

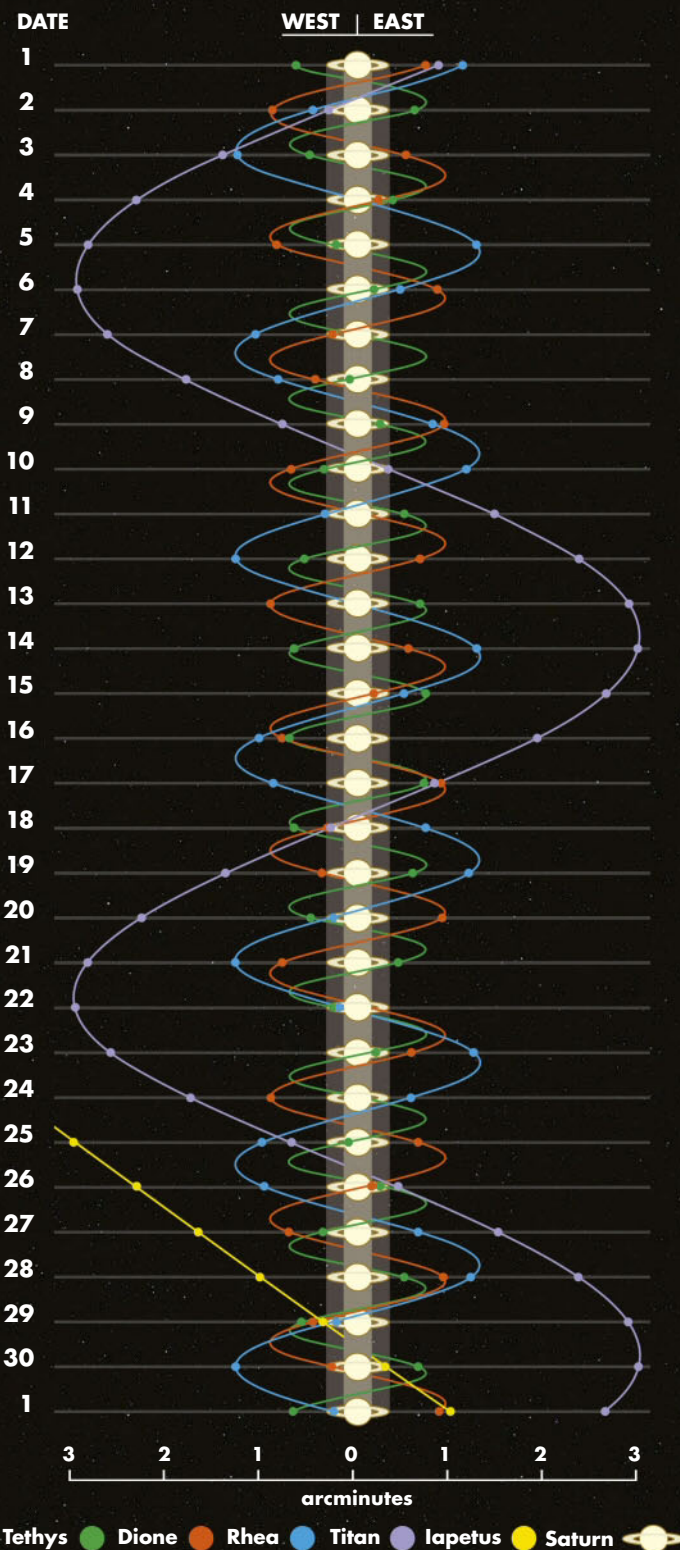
Saturn is now becoming quite low as darkness falls, a situation that gets worse as the month progresses. Saturn shines at mag. +0.5 for most of the month, dipping slightly to mag. +0.6 for the last week. It currently lies in the southern part of Ophiuchus, close to the Serpent Bearer's western foot, and forms an equilateral triangle with mag. +1.0 Antares (Alpha (α) Scorpii) and Mars on 1 September.

## JUPITER

Jupiter is not visible in a conventional way this month but there's a chance to see it in a daylight occultation – see page 51. The planet is in conjunction with the Sun on 26 September.

# SATURN'S MOONS September

Using a small scope you'll be able to spot Saturn's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



## YOUR BONUS CONTENT

Planetary observing forms



# The Northern Hemisphere

## KEY TO STAR CHARTS

- Arcturus** STAR NAME
- PERSEUS CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- ASTERISM
- PLANET
- QUASAR
- STAR BRIGHTNESS:**
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

## WHEN TO USE THIS CHART

1 SEPTEMBER AT 01:00 BST  
15 SEPTEMBER AT 00:00 BST  
30 SEPTEMBER AT 23:00 BST

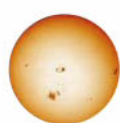
On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

## HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.



## THE SUN IN SEPTEMBER\*



| DATE        | SUNRISE   | SUNSET    |
|-------------|-----------|-----------|
| 1 Sep 2016  | 06:19 BST | 19:58 BST |
| 11 Sep 2016 | 06:37 BST | 19:34 BST |
| 21 Sep 2016 | 06:54 BST | 19:10 BST |
| 1 Oct 2016  | 07:12 BST | 18:45 BST |

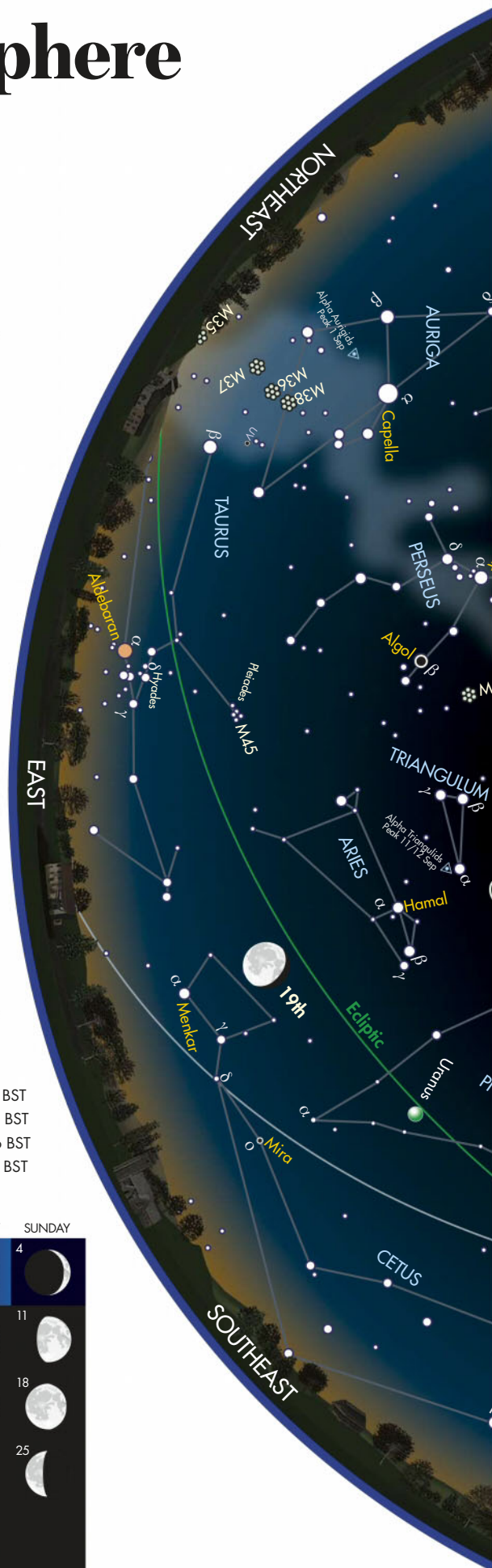
## THE MOON IN SEPTEMBER\*



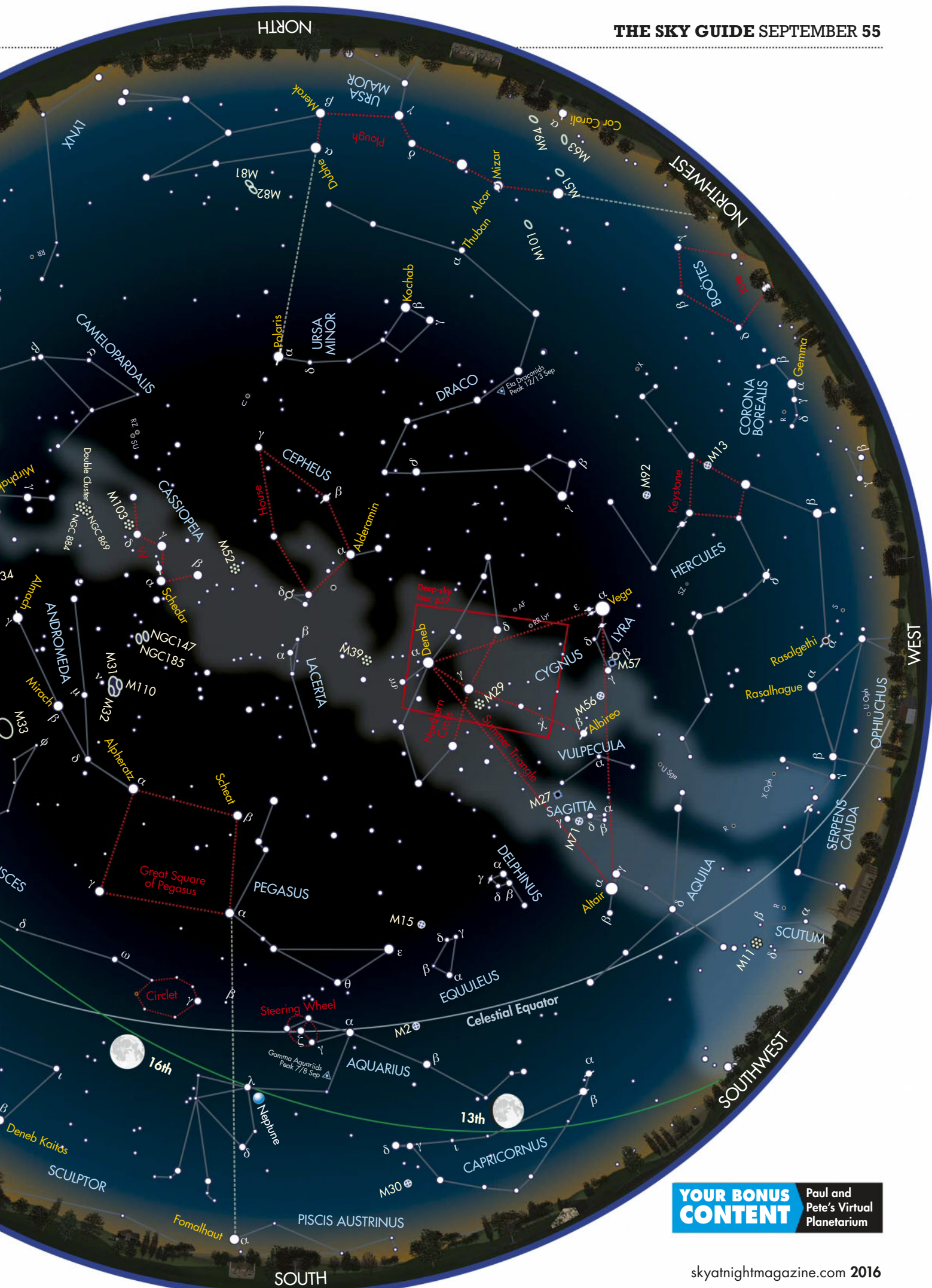
| MOONRISE TIMES         |                        |
|------------------------|------------------------|
| 1 Sep 2016, 06:17 BST  | 17 Sep 2016, 19:51 BST |
| 5 Sep 2016, 10:42 BST  | 21 Sep 2016, 22:04 BST |
| 9 Sep 2016, 14:47 BST  | 25 Sep 2016, 00:46 BST |
| 13 Sep 2016, 17:52 BST | 29 Sep 2016, 05:14 BST |

\*Times correct for the centre of the UK

| MONDAY | TUESDAY | WEDNESDAY | THURSDAY      | FRIDAY          | SATURDAY | SUNDAY |
|--------|---------|-----------|---------------|-----------------|----------|--------|
|        |         |           | 1<br>NEW MOON | 2               | 3        | 4      |
| 5      | 6       | 7         | 8             | 9               | 10       | 11     |
| 12     | 13      | 14        | 15            | 16              | 17       | 18     |
| 19     | 20      | 21        | 22            | 23<br>FULL MOON | 24       | 25     |
| 26     | 27      | 28        | 29            | 30              |          |        |







**YOUR BONUS  
CONTENT**

Paul and  
Pete's Virtual  
Planetarium



# Deep-sky tour

Six superb star clusters and planetary nebulae in the constellation of Cygnus, the Swan

✓ Tick the box when you've seen each one



The crescent shells of NGC 6888 are sculpted by the nebula's central star

1

## NGC 6871

☞ You'd think that a mag. +5.2 open cluster would be ideally suited to small telescope viewing but – being located against the Milky Way running through Cygnus – NGC 6871 is easy to lose against the myriad background stars. It lies 5.5° southwest of mag. +2.2 Sadr (Gamma (γ) Cygni) and 2° east-northeast of mag. +3.9 Eta (η) Cygni. The cluster occupies a region roughly 25 arcminutes across and is located 5,135 lightyears away. It appears as a trail of nine bright stars running south from mag. +5.4 27 Cygni. Larger scopes using low magnifications (up to 100x) will bring out the wonderful colours of many closely associated double stars located within the cluster. ☐ SEEN IT

2

## NGC 6883

☞☞ Look 1° to the east of NGC 6871 and you'll come to another open cluster, NGC 6883. Again, the rich star background of the Milky Way doesn't help here. Through a small telescope you may have the same issue as with NGC 6871, in that the cluster itself appears barely distinguishable from the background. However, a 10-inch scope starts to reveal stars in the 4-arcminute heart of the cluster – approximately 12 of them concentrated in this region. NGC 6883's total apparent size edges up to around 15 arcminutes across. Look out for a pair of bright red supergiant stars which define the cluster's western boundary. ☐ SEEN IT

## THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.



3

## THE CRESCENT NEBULA

☞☞ The Crescent Nebula, NGC 6888, can be found three-fifths of the way along a line from Eta Cygni to Sadr. Look for a small diamond-shaped pattern of stars: the nebula's brightest portion crosses the triangular eastern half of this diamond. NGC 6888 looks remarkably pear-shaped through a large scope, approximately 16 arcminutes long. The nebula is being produced by the brightest star at its centre (HIP 99546). Material shed from this star at different stages of its life is interacting with the star's fast stellar wind, forming the crescent shells of the nebula. It can be a frustrating visual target, appearing dimmer than its 10th-magnitude listing would suggest. A UHC filter (or better still, OIII filter) will really help. Keep the magnification low, around 60-80x. ☐ SEEN IT

4

## M29

☞ M29 is one of only two Messier objects in Cygnus, a 7th-magnitude open cluster that sits 1.75° south and slightly west of Sadr. A small telescope reveals the 7 arcminute cluster easily, while a 6-inch instrument will show around 15 stars, the brightest of which form a box with open flaps. An alternative name for M29 is the rather unappealing Cooling Tower Cluster because the open box resembles that of a power station's cooling tower. Its distance is uncertain because its light is attenuated by material lying along the plane of the Milky Way. Current estimates suggest either 7,200 or 4,000 lightyears away. ☐ SEEN IT

5

## THE ROCKING HORSE CLUSTER

☞ Our next target is open cluster NGC 6910, 0.5° north of Sadr. Two brighter orange stars appear to straddle the cluster. Fainter stars between them create the profile of a rocking horse, hence this is known as the Rocking Horse Cluster. The two brighter stars are interesting: The northern one shines at mag. +7.3 and has a spectral classification of K1III, which is why it appears orange. However, the marginally brighter mag. +7.0 southern star has a classification of B1 which would suggest a blue-white colour, yet it appears orange too. This occurs because its light has to pass through intervening galactic dust, which scatters the blue light, leaving mostly red. ☐ SEEN IT

6

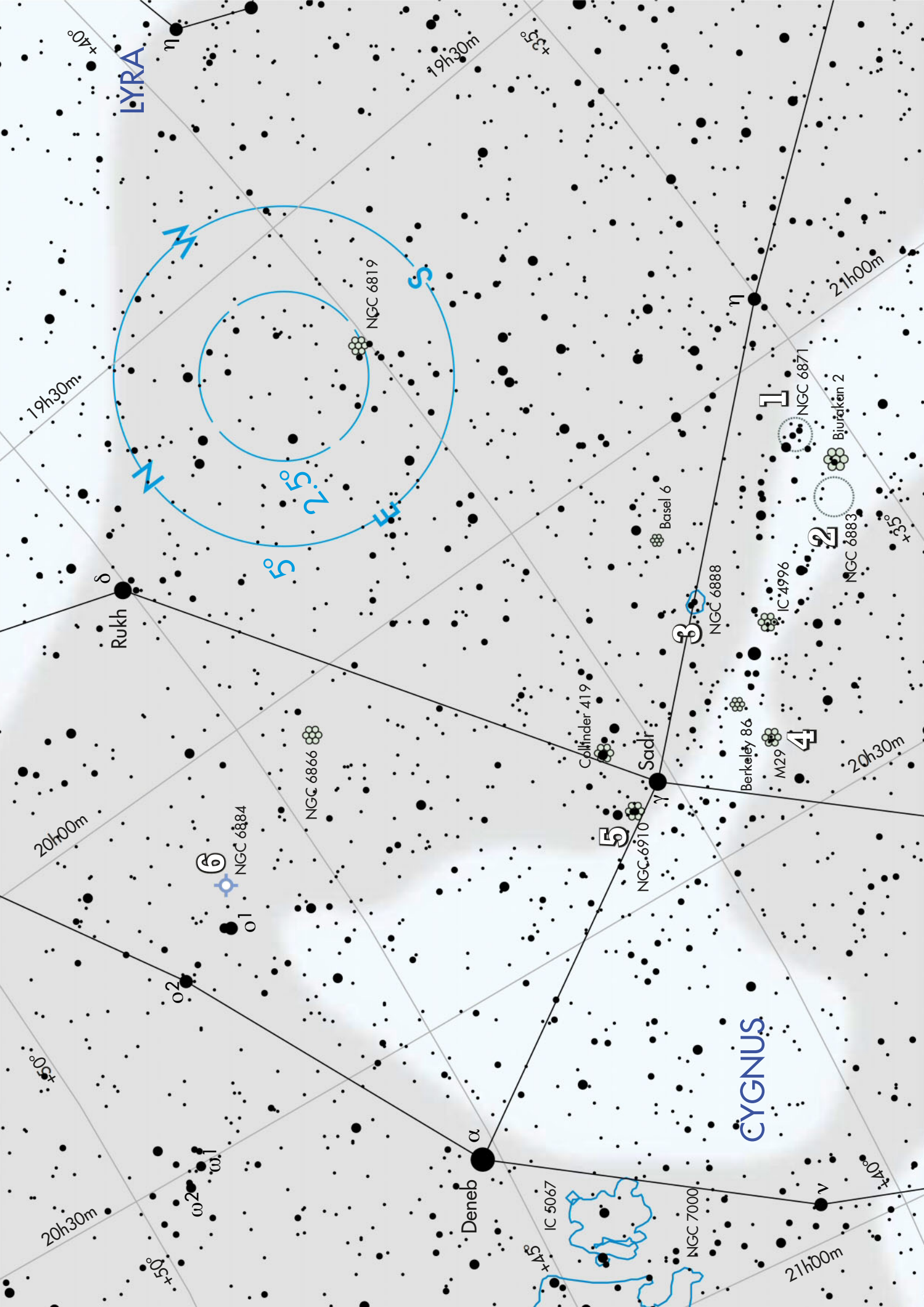
## NGC 6884

☞ We head a bit farther north for our final target, the planetary nebula NGC 6884. This lies 37 arcminutes to the west-southwest of the naked eye optical double star, Omicron<sup>1</sup> (ο<sup>1</sup>) Cygni; mag. +3.8 and +4.8 separated by 5.5 arcminutes. The planetary nebula appears as a tiny blue disc, approximately 6 arcseconds in diameter. While the nebula falls short on size, its surface brightness is relatively high and at around 100x magnification it appears like a slightly out of focus star. A 12-inch scope at 200x will show its small blue disc well. As with many planetaries, an OIII filter can really help make it stand out. ☐ SEEN IT

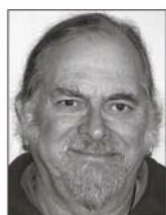
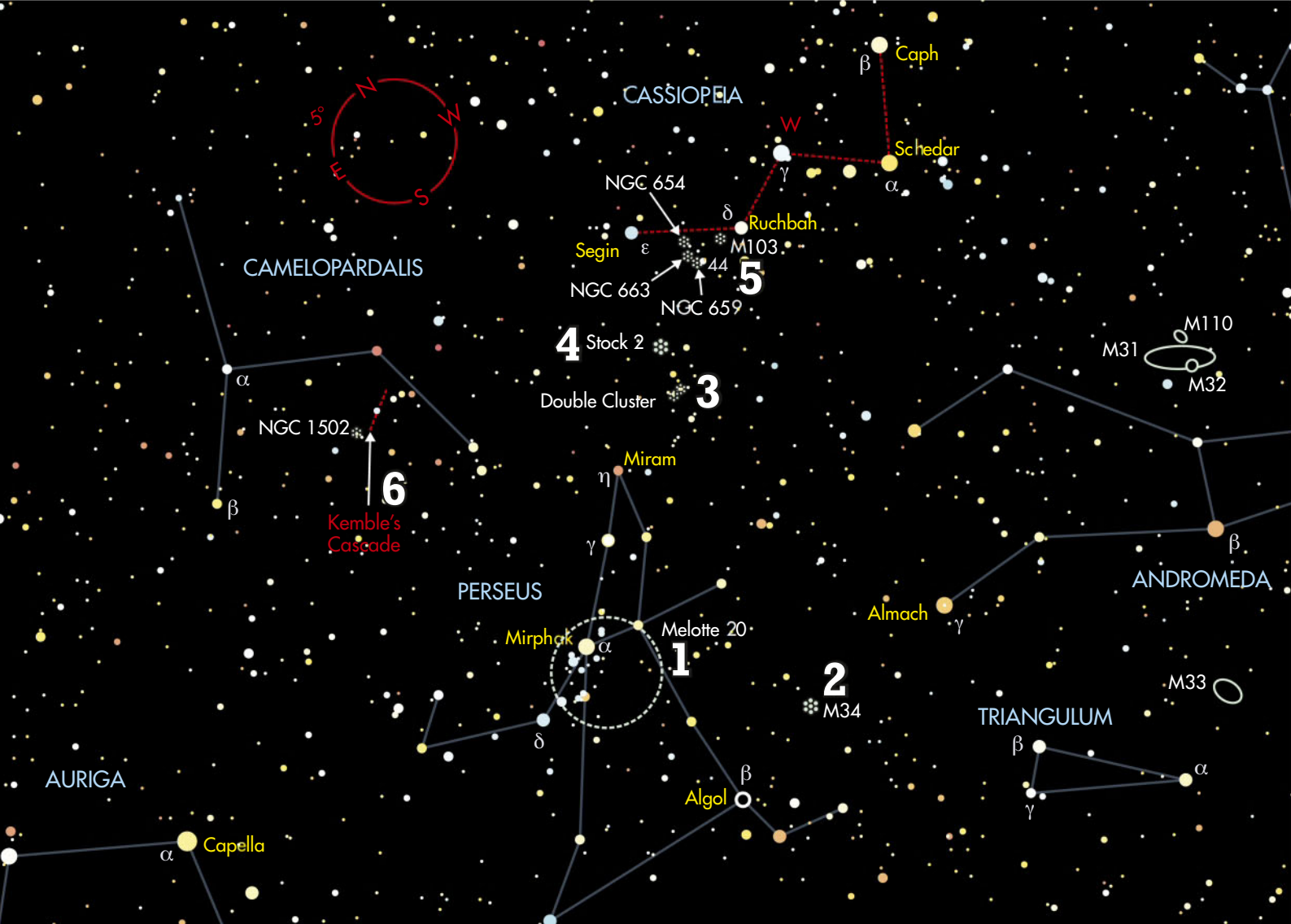
## YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour









With  
**Stephen Tonkin**

## Binocular tour

September offers a posing bodybuilder and a slew of clusters ideal for binoculars

☑ Tick the box when you've seen each one

### 1 MELOTTE 20

**10x 50** We start with a target that is easy to see and ideal for binoculars, extending as it does for nearly 4°. Melotte 20, otherwise known as the Alpha Persei Moving Cluster, is an association of mostly of young blue stars around mag. +1.8 Mirphak (Alpha (α) Persei). You should easily be able to see more than 50 stars. The cluster is only 60 million years old and is said to be 'moving' because all of its stars share a similar proper motion (that is, motion relative to the celestial sphere) of around 33 milliarcseconds per year. ☐ **SEEN IT**

### 2 M34

**10x 50** From Melotte 20, navigate 10° in the direction of Triangulum. Here you should find a fuzzy patch that has a similar apparent size to the Moon. This is M34, which is a superb cluster in binoculars of any size. It is visible to the naked eye with averted vision on a transparent night. Depending on your sky conditions, a pair of 10x50s can resolve a dozen or more stars,

the brightest of which form a curved H shape. The cluster spans about 14 lightyears. ☐ **SEEN IT**

### 3 THE DOUBLE CLUSTER

**15x 70** To find our next target, imagine a line joining mag. +2.5 Gamma (γ) Cassiopeiae to mag. +2.7 Ruchbah (Delta (δ) Cassiopeiae) and extend it for twice its length again, which will take you into Perseus. Here you will find a close pair of open clusters, NGC 884 and 869. Although they can be visible to the naked eye, you really need a pair of 15x70s to tease out their qualities: big binoculars reveal the varying colours and brightnesses of the stars. Those stars are intrinsically much brighter than the Sun, which would be invisible in binoculars at the same distance. ☐ **SEEN IT**

### 4 THE MUSCLEMAN CLUSTER

**10x 50** If you look at the part of the Double Cluster that is nearest to Cassiopeia, you will see a 2°-long chain of 8th-magnitude stars going north. They lead to Stock 2, the Muscleman Cluster. This

sparse open cluster gets its name from the pattern of brighter stars, which have the form of a stick man in muscle-flexing bodybuilder pose, pulling this chain of stars off the Double Cluster. This is purely a line-of-sight phenomenon: the Muscleman is only 1,050 lightyears away, a mere 15 per cent of the distance to the Double Cluster. ☐ **SEEN IT**

### 5 NGC 654, 659 & 663

**15x 70** Perseus has the Double Cluster, but Cassiopeia has a triple! Imagine a line joining mag. +3.4 Segin (Epsilon (ε) Cassiopeiae) to Ruchbah, and look about a 1° below its midpoint. Here you will easily find the richest of these clusters, NGC 663. The four brightest stars appear to be separated into pairs by a dark lane. About 0.75° to the north-northwest is NGC 654, a small comet-shaped patch of light just next to a mag. +7.3 star. The faintest of the trio is NGC 659, a tiny ghostly glow which may need averted vision, just on the NGC 663 side of the star 44 Cassiopeiae. ☐ **SEEN IT**

### 6 KEMBLE'S CASCADE

**10x 50** We finish with another object that is best in binoculars. Imagine a line from mag. +2.3 Caph (Beta (β) Cassiopeiae) to Segin, and extend it for the same distance again. You will find an almost straight line of 15 8th-magnitude stars extending for about 2.5°. There is a brighter (5th-magnitude) one in the middle. In late summer evenings the asterism is almost vertical, and appears as a thin, ribbon-like waterfall of stars, with a splash-pool (the open cluster NGC 1502) at the bottom. ☐ **SEEN IT**



# Moonwatch

## Cavalerius

CAVALERIUS IS A fine example of a lunar crater. It has a diameter of 58km and is located on the western shore of Oceanus Procellarum. To the north and east is the dark lava floor of the ocean, interrupted by the eye and swirl patterns of the albedo feature Reiner Gamma. To the west and south is an area of bright highland material.

Cavalerius lies at the northern end of a run of craters starting with the dark-floored plain Grimaldi (222km wide). This makes a great place to begin for locating Cavalerius as Grimaldi is extremely prominent and easy to see. As an aside, when the Moon is full or in the waning gibbous phase, see if you can locate Grimaldi with just your eyes. It should be possible, although it's probably on the limit or perhaps slightly below it for many.

Immediately north of Grimaldi is Lohrmann (31km), which looks tiny but is still an easy spot in a 2-inch telescope. Its walls surround a flat floor pockmarked with tiny craterlets, many of which are too small to be seen with small instruments, simply providing texture to Lohrmann's floor. Further north still is Hevelius (106km), another great example of a lunar walled plain. The crater's battered rim surrounds a flat floor made distinct by the prominent Hevelius A (14km).

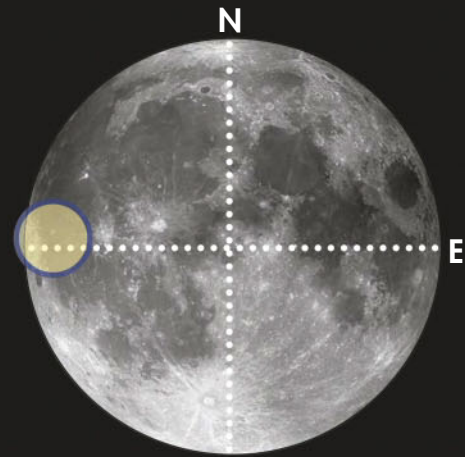
Cavalerius touches the northern edge of Hevelius, and in comparison to the more southern craters described it looks like a classic lunar crater. It has prominent terraced walls leading to a floor 3.3km below. The floor has a central mountain complex comprising three peaks arranged in a north-south orientation. The central peaks rise 1.1km above

the crater floor below. As it is close to the western limb, we get a highly foreshortened view of Cavalerius, which hides some of its detail. Images taken by orbiting spacecraft show its rim to have two small extensions – one in the north and one in the south. Taken together, they give the rim a lemon-like shape.

Under bright illumination, when the Reiner Gamma is prominent, it is possible to see bright streaks emanating from Cavalerius. These are more evident southeast of the main crater as they cross the floor of the Oceanus Procellarum. Whether they are only due to

### STATISTICS

**TYPE:** Crater  
**SIZE:** 58km diameter  
**AGE:** 1.1-3.2 billion years  
**LOCATION:** 5.1°N, 66.9°W  
**BEST TIME TO OBSERVE:** Six days after first quarter or five days after last quarter (14-15 September and 28-29 September)  
**MINIMUM EQUIPMENT:** 2-inch telescope

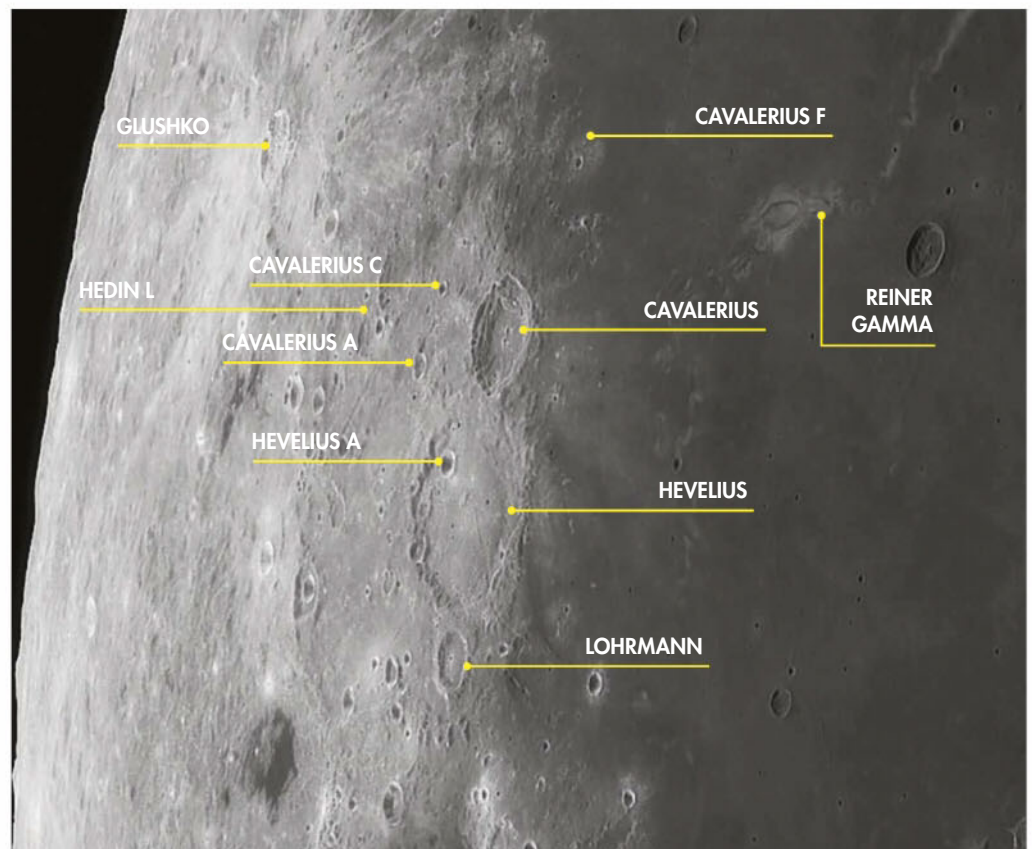


the impact that created Cavalerius is unclear, as the impressive ray crater Glushko is also responsible for some dramatic rays in the area.

Cavalerius A (14km) is west and slightly south of Cavalerius. To its north is Cavalerius C (8km). This pair form a rather nice, almost-equilateral triangle with Hedin L (10km) farther west.

Some 104km north and slightly east of Cavalerius is Cavalerius F (7km), itself surrounded by a lighter patch of material. The Luna 9 spacecraft went into the history books on 3 February 1966 as it made the first ever soft landing on the Moon's surface in the region just to the south of Cavalerius F.

## “Close to the western limb, we get a foreshortened view of Cavalerius”



▲ Compared to those to the south of it, Cavalerius appears to be a classic lunar crater



# Astrophotography

## Neptune and the Moon



### RECOMMENDED EQUIPMENT

High frame rate camera, 6-inch or larger telescope, optical amplifiers to achieve an effective focal length of 2-4m, red filter for monochrome cameras



Our final composite image, showing tiny Neptune creeping away from the Moon

MAG. +7.8 NEPTUNE is the dimmest planet in our Solar System. This is a consequence of its great distance from both the Sun and Earth. Neptune reaches opposition, the point when it's opposite the Sun in the sky, on 2 September. Two weeks on, a full Moon will join it in the sky. The full phase represents the time when the Moon reaches its own opposition. On 15 September, a day before it is full, the Moon will appear to pass in front of Neptune in an event known as a lunar occultation.

The occultation disappearance occurs at 20:06 BST (19:06 UT) when the sky will still be bright and the Moon low. The Sun will be below the horizon however, and there is a chance that large-aperture instruments will be able to reveal the planet if the sky is very clear. However, this is not an optimal disappearance for most setups. Neptune's reappearance, on the other hand, offers much better prospects. This occurs at 20:55 BST (19:55 UT) when the Moon is 15° up and the sky

significantly darker. Setting your scope on the correct part of the Moon's limb, will allow you to see Neptune as it emerges from behind the Moon's disc. If you have a camera fitted, then this is a great opportunity to image both together.

### Exposure issues

The settings are crucial of course. Neptune is a dim object, which would normally require much longer exposures than you'd use for the much brighter full Moon. Consequently, if you set the camera for Neptune, the Moon's disc will overexpose.

There are various options available to help deal with this huge dynamic range. If you set your camera for the lunar surface during reappearance, it's unlikely that Neptune will register. So the only way to get a shot of reappearance is to opt for an overexposed lunar surface. If you want to produce a high dynamic range

composite showing Neptune as a tiny disc next to a correctly exposed lunar surface, this can be done by combining two images – one correctly exposed for Neptune and another done either before or after the occultation, correctly exposed for the Moon. Combining the two will produce a false image which shows the relative sizes and scale of the event. The Moon's apparent diameter will be in the order of 870x that of Neptune's disc, due to 49,244km-diameter Neptune being 12,073 times farther away than our 3,474km-diameter Moon.

It a good idea in these circumstances to create a final image with text on it describing the techniques used to produce the shot. This will avoid any misunderstandings that may occur as to how the shot was taken. You can go further by including a sequence of overexposed Moon images showing the position of Neptune as it emerges from behind the Moon's limb.

Additional imaging opportunities occur after reappearance, when the pressure is off. Catching a shot of Neptune's apparently tiny disc next to the Moon's much larger apparent disc can produce a stunning shot. A DSLR with a lens or telescope with a focal length up to around 1,000mm should be an ideal combination to record the Moon and Neptune. Here too, the large difference in apparent brightness between them will typically require a composite in order to show them properly exposed at the same time.

### KEY TECHNIQUE

#### CAPTURING THE ESSENCE

Some astronomical events are beyond a camera's dynamic range capability to image correctly. At these times a bit of creativity is required to convey the essence of the view. Since exposing for the Moon and Neptune at the same time isn't feasible the final image has to be created from separate elements and composited together to show the difference in apparent size.

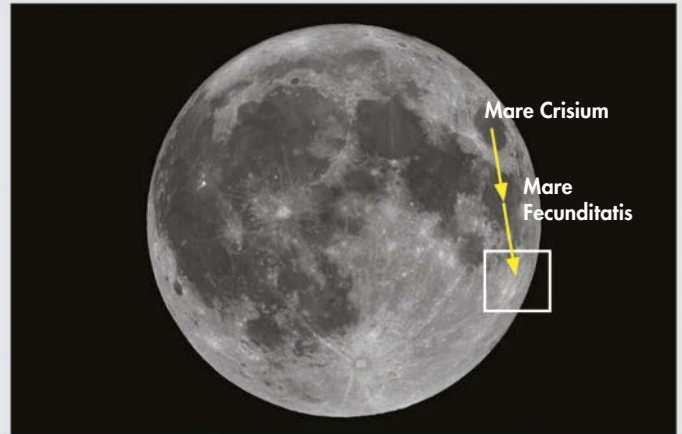
✉ Send your image to: [hotshots@skyatnightmagazine.com](mailto:hotshots@skyatnightmagazine.com)



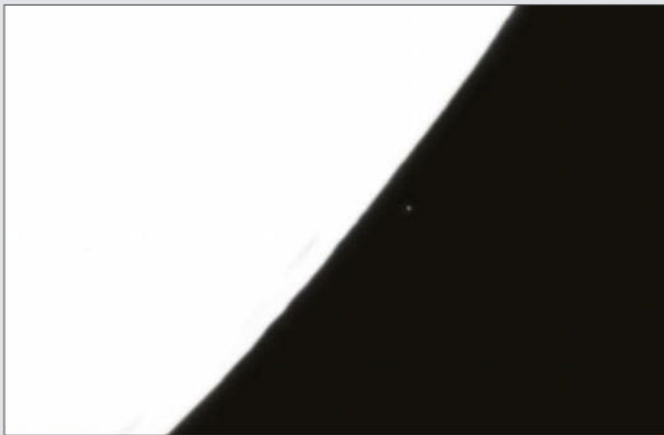
# STEP-BY-STEP GUIDE

## STEP 1

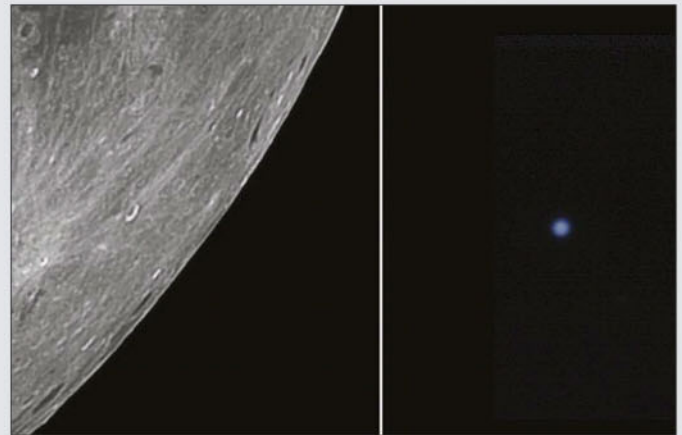
Practice makes perfect, so obtain a shot of Neptune before 15 September. Experiment with focal length and camera settings to get an optimal image of the planet. Note these settings. If you're using a monochrome high frame rate camera, consider adding a red filter. A focal length of 2-4m is a good starting point and may be achieved by using an optical amplifier such as a Barlow lens if necessary.



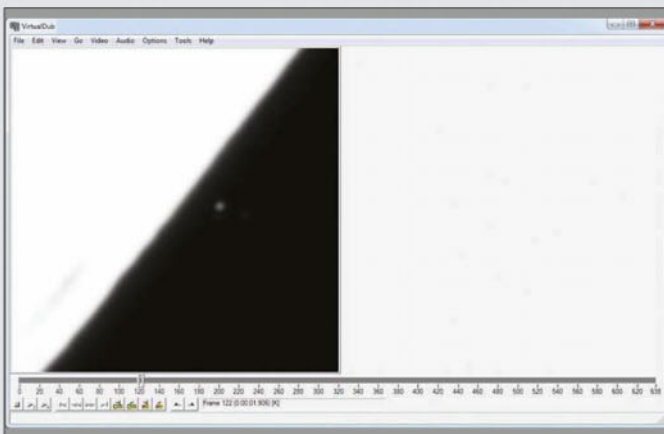
**STEP 2** It's important to be looking at the right part of the Moon's limb: locate the centre of the Mare Crisium, then imagine a line through the centre of the Mare Fecunditatis until you hit the Moon's southeast limb, as shown. Reappearance occurs a fraction north of here. Focus sharply on the Moon's edge at least 15 minutes before the event.



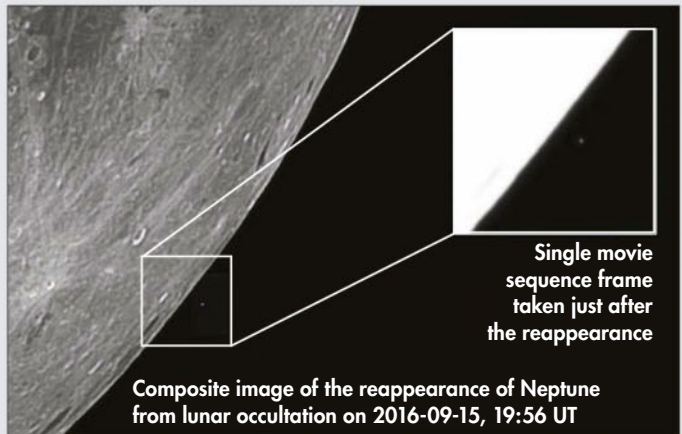
**STEP 3** Set the camera to the settings for Neptune you recorded in Step 1. It takes about six seconds for Neptune's disc to fully emerge from behind the Moon. Record a continuous video of the reappearance. Keep recording until Neptune is obviously clear of the Moon's limb, with a noticeable separation between the Moon and the planet.



**STEP 4** Approximately 20 minutes after reappearance, Neptune and the Moon will have separated enough to put the Moon out of the frame. Continue imaging Neptune as you would normally. Then image the Moon's edge at a suitable exposure. Consider mosaicing a larger section of the Moon's disc or even the whole disc if practical.



**STEP 5** Open your video using the freeware VirtualDub ([www.virtualdub.org](http://www.virtualdub.org)). Step through the video to the point just after total reappearance. When a sharp frame appears, copy and paste it into your preferred graphics editor. This will be your background template. Paste the section of Moon in as a new upper layer.



**STEP 6** Align the correctly exposed Moon to the overexposed version on the bottom layer. Cut an enlarged selection around your correctly exposed Neptune image and paste into the composite as the top layer, then align Neptune. Set the top layer's blend mode to Lighten. Finally, add explanatory text and an inset showing a small version of the bottom layer.

SIMULATION



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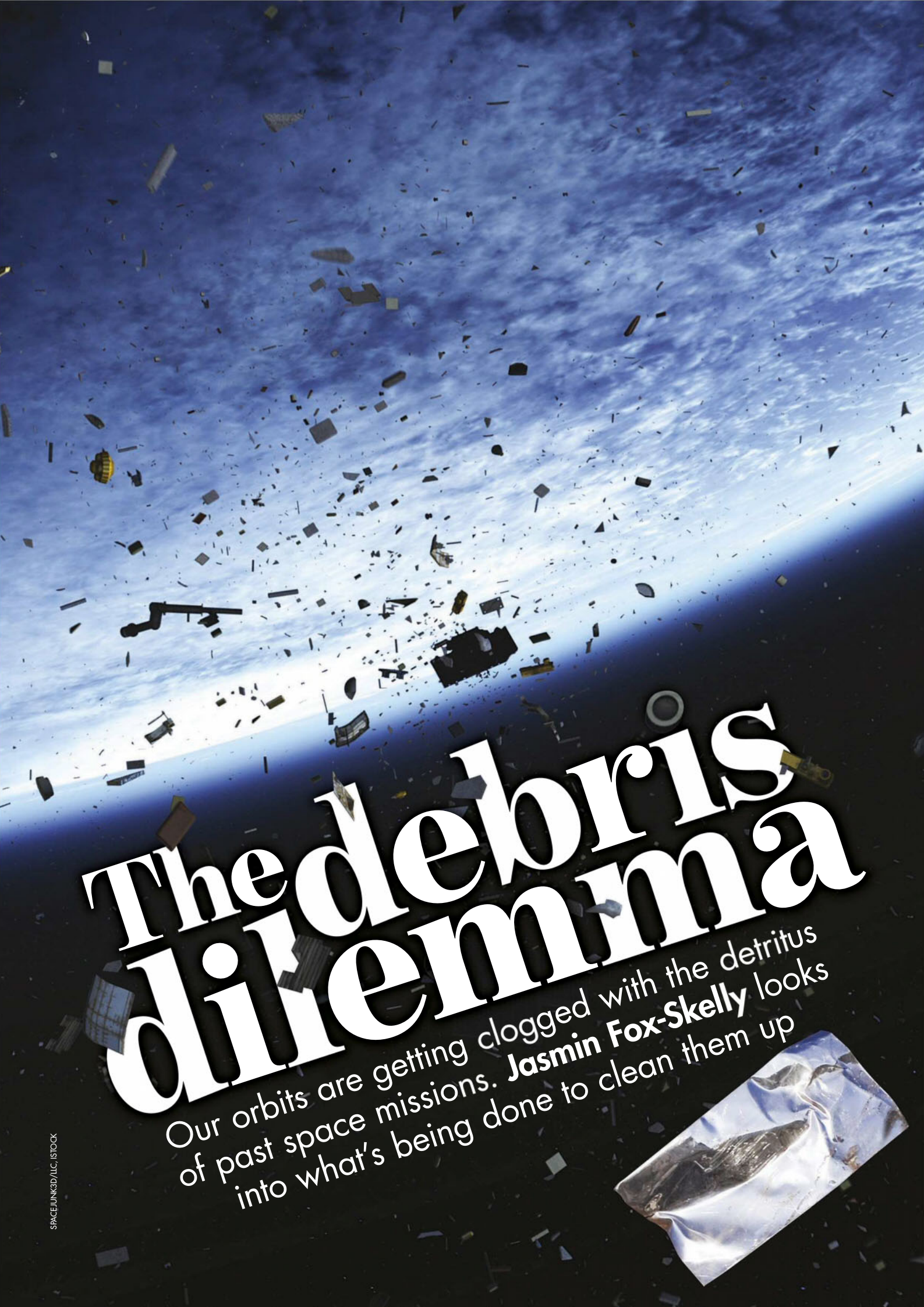
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# The debris dilemma

Our orbits are getting clogged with the detritus of past space missions. **Jasmin Fox-Skelly** looks into what's being done to clean them up





Orbiting the Earth at over 28,000km/h is the world's biggest rubbish heap. Nuts and bolts whizz past paint flakes, dead batteries and human waste, the detritus dumped or lost during human space missions. The very first American spacewalker, Ed White, even left a glove behind.

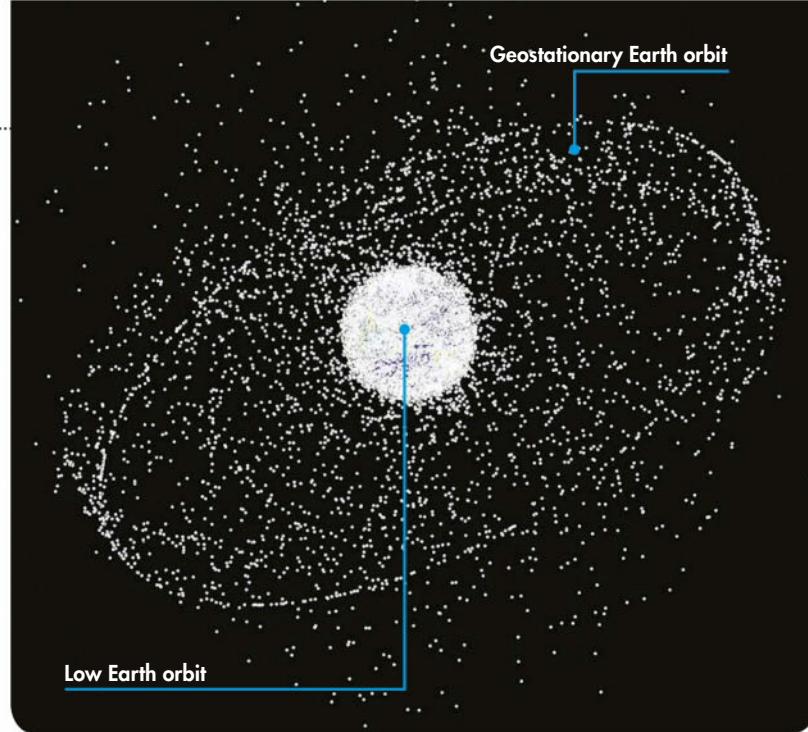
This space junk is not benign: a small piece of paint travelling at such great speed has considerable energy, while an object just 1cm across packs the punch of an exploding hand grenade. There are millions of these fragments in space posing a threat to astronauts and spacecraft. And these are just the small objects.

It's the big ones that matter most though. Since Sputnik was launched in 1957, over 6,600 satellites have been fired into orbit. Over years most of those have become derelict husks, clogging up the space highways with no way to control them. Along with spent rocket stages, these make up the bulk of the mass of space rubbish.

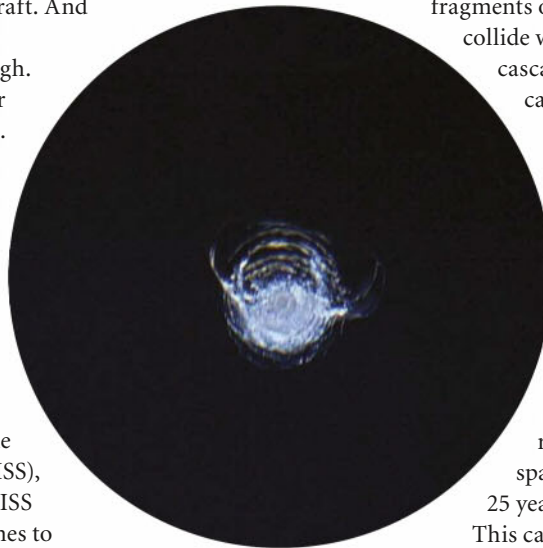
Most space litter is found in low Earth orbit, the area of space nearest to the Earth, between 160km and 2,000km up. Unfortunately this zone houses the International Space Station (ISS), which is about 400km above Earth. The ISS has had to take evasive action several times to avoid disastrous collisions.

The other danger zone is much higher up, in geostationary Earth orbit 35,785km above Earth's equator. This is the most popular place to put commercial weather, communications and surveillance satellites, as the speed at which they travel directly matches that of the Earth's rotation – which effectively means they sit above the same place permanently.

This makes the orbit incredibly overcrowded, with satellites jostling each other for space. The busy highway can only take so much traffic, so regulations dictate that after they have reached the end



▲ Space junk is a pressing concern in these two critical Earth orbits



▲ This chip in the ISS's Cupola window was likely caused by a tiny piece of debris – a paint flake

of their lifespan they should be moved to nearby 'graveyard orbits' to make room.

If satellites here were destroyed by debris you'd have to say goodbye to mobile phones, GPS, weather forecasts, live TV and the internet. More seriously, global communication systems, transport, the national grid and computer systems would all fail.

What's more, a collision would risk setting off a disastrous chain reaction, as when just two objects of space litter hit each other they break apart creating hundreds more fragments of space shrapnel. Those pieces then collide with others, leading to an exponential cascade of collisions. This phenomenon is called the Kessler syndrome, after NASA scientist Donald J Kessler.

## Averting disaster

So what is being done? Well the first step is to make sure that all space vehicles and satellites sent up to space have a way of getting back down again, or at least of being pushed into a less-crowded orbit.

Most spacefaring nations now have rules in place that any craft put into space must be removed from orbit

25 years after the end of its useful lifespan.

This can be achieved by slowing spacecraft down enough so they can re-enter the atmosphere, allowing them to burn up on re-entry. Bits may still make it through the atmosphere, but they can be directed to land in the middle of the Pacific Ocean.

One way of slowing a spacecraft down is by using a rocket, but proposals have even been made to use solar sails, which would act like a parachute. This is more of a mitigation strategy aimed at not making the problem even worse, but how do we get rid of the cosmic rubbish already up there?

A range of technological solutions have been proposed including capturing debris using nets, ►



Deorbiting defunct satellites would allow them to harmlessly burn up on re-entry



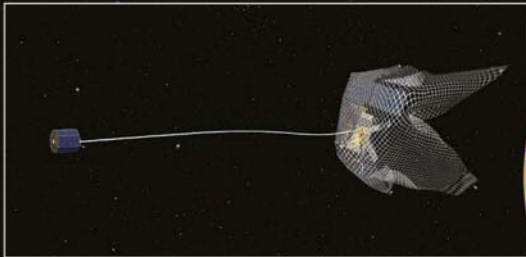
# THE CLEAN-UP CREW

Several technologies are being developed to take care of space junk



## Laser cannon

Scientists in Japan have designed a laser that could be installed on the ISS to vaporise debris. On larger fragments the laser would act like a jet, slowing down the debris. Over time this would cause the targeted junk to fall to Earth.



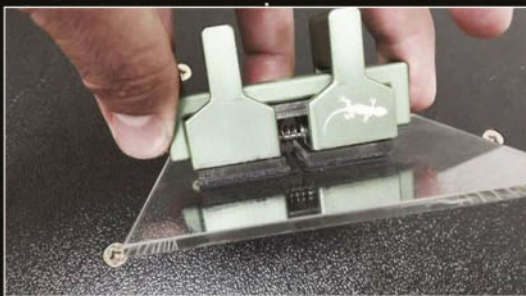
## E.deorbit

ESA plans to launch a debris clean-up mission called E.deorbit in 2023. It will use a net or a robotic arm to capture a derelict Envisat satellite in low-Earth orbit. The satellite will then be dropped down to the atmosphere where it can safely burn up.



## Making engine propellant from space junk

Chinese scientists have designed an engine that converts space debris into fuel. Their idea is to capture the debris using a net and then transfer it to a ball mill, which would grind the debris into powder. This powder would then be heated into a plasma and fed into a system, eventually being turned into propellant.



## Gecko Grippers

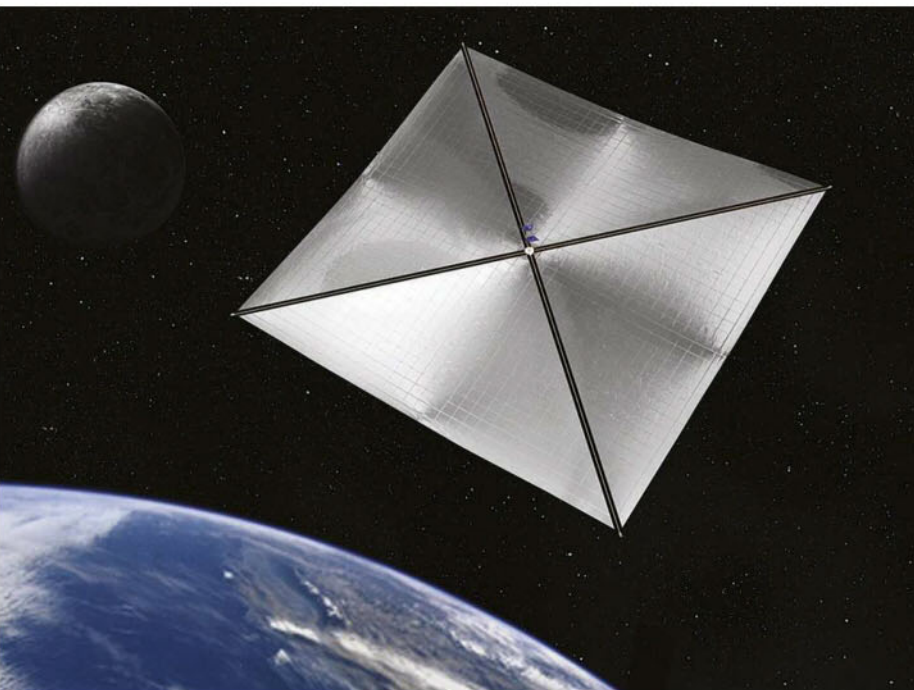
Geckos use small hairs on their feet called setae to stick to almost anything. Scientists have copied the idea and made adhesive grippers that can stick to the sides of orbital junk, allowing them to be pulled out of the way. The grippers are currently being tested on the ISS.



## CleanSpace One

In 2018, the Swiss University EPFL plans to capture a defunct SwissCube satellite with a spacecraft called CleanSpace One. A folding net will be sprung at the spinning piece of space junk to trap it, and then CleanSpace One will re-enter the atmosphere. It's something of a suicide mission as both debris and CleanSpace One will then burn up.





► harpoons and robotic arms, so it can then be safely dragged to a higher altitude or de-orbited to burn up in the atmosphere. Another idea is to use a laser cannon to zap debris. A team of researchers at the RIKEN lab in Japan has come up with a prototype 10-Watt laser, which would be mounted on the ISS and is capable of firing 100 laser pulses a second. If successful, it could ultimately lead to a 500,000-Watt laser able to fire 50,000 times per second, which could remove 100,000 pieces of rubbish a year from low-Earth orbit.

Other researchers have taken their cue from nature and designed 'gecko-like' grippers that can snatch debris from the sky. Geckos have specialised hairs on their feet called setae that let them stick to vertical surfaces without falling. The grippers work in a similar way, with special adhesive pads containing synthetic hairs called stalks. When they come in contact with an object

▲ **Solar sails have been proposed as one way of slowing debris down so it can be deorbited**

▼ **Over 6,600 satellites have been fired into orbit since Sputnik, and most of them are still up there**

such as space debris, the force of the contact bends the stalks, which increases their stickiness. The grippers could be used on the sides of spacecraft, fuel tanks, and other similarly smooth objects to grip space debris.

"A lot of space debris is retired satellites and rocket bodies that have a large area of smooth surfaces, either metal or solar panels," says Hao Jiang at Stanford University who is working on the tech. "Since our gecko adhesive gripper only needs a very small pressing force to adhere to smooth surfaces, it is the perfect candidate for this application as we can easily acquire and grapple these floating objects in space."

## The elephant in the room

Another idea is to develop an engine that can actually convert captured space debris into fuel propellant, giving it the power to continue gobbling up rubbish. But the problem with many tech solutions is that they risk creating more debris, as they could break up the garbage into even smaller and smaller pieces.

They're also very expensive, raising the awkward elephant in the room of just who should pay for all this. The issue affects everyone, but no one is specifically responsible. Another problem is that, debris or no debris, many of the satellites out there are private property, so even if they no longer work it would be illegal to destroy them. Current space treaties mean you need permission from the original owner before anything can be destroyed. The ultimate danger is that the longer you wait to clean up space, the more likely a disastrous collision. **S**



### ABOUT THE WRITER

Jasmin Fox-Skelley is an astronomy and science writer based in Cardiff. She has a BSc in Neuroscience and an MSc in Science Communication.





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# TO BOLDY (TOUCH AND) GO

This month, NASA launches OSIRIS-REX to analyse an asteroid, and in doing so answer fundamental questions about the origins of the Solar System, as **Ben Gilliland** explains

**T**he question of where we came from has obsessed humanity from its earliest days. Long before the invention of

the written word, early humans were sketching creation myths on the walls of caves and imagining how the world around them came to be.

Today we have resources that stretch well beyond mere imagination, but the precise mechanisms that forged the Solar System remain poorly understood.

To get a true insight into the dawn of our existence we need to examine a pristine sample – a nugget of pure, early Solar System untainted by the ravages of time.

Asteroids are the detritus left over from the formation of the Solar System. They never made it into planets or moons and, as such, are time capsules preserved

for 4.6 billion years. Get a sample of an asteroid and you have a sample of the building blocks of the Solar System itself. This is the goal of NASA's first asteroid sample-return mission, OSIRIS-REX. Set for launch on 3 September 2016, OSIRIS-REX will rendezvous with the asteroid

carbonaceous, or B-type, asteroid that is rich in volatiles potentially containing water and organic molecules. Secondly, Bennu has a diameter of about 500m, which means it isn't tumbling through space so quickly that a craft would be unable to safely collect a sample (the

smaller an asteroid's diameter, the faster its rotation). Thirdly, Bennu is classed as a near-Earth object. It travels close enough to Earth to make a sample-return mission practical, and its orbit has a low eccentricity, which means

**“Understanding what makes Bennu tick might one day help save the human race”**

Bennu (1999 RQ36) in 2018, perform an extensive survey and return a sample of the space rock to Earth in 2023.

Bennu was selected as a target from the 500,000 known asteroids because it is one of only five of that number that fulfil a number of crucial criteria. Firstly, it is a

it never travels too close or too far from the Sun (important when your spacecraft relies, in part at least, on solar power).

Bennu is a potential Earth-impactor and there is a chance (albeit only one in 2,500) that it could collide with Earth sometime towards the end of the 22nd century. Understanding what makes it tick might one day help save the human race.

## Two-year journey

OSIRIS-REX will take two years to reach Bennu – during which time it will slingshot around Earth, using the planet's gravity to accelerate to just under 20,000km/h, the speed it needs to intercept the asteroid, which itself is hurtling around the Sun at over 101,000km/h. Once the craft is within about 5km of Bennu, it will spend 505 days mapping the asteroid's surface – using its suite of cameras, altimeters and spectrometers to study its chemistry, mineralogy and typography, as well as making a precise determination of its orbit.



The TAGSAM arm will collect the sample from Bennu; here it is being tested in the lab



NASA will use the latter information to determine how something called the Yarkovsky effect influences the orbit of an asteroid. As an asteroid orbits the Sun, one side of it is heated by solar radiation. When the asteroid turns and the heated side is plunged into darkness, that heat is radiated into space producing a tiny bit of thrust that, over centuries, can alter its orbit: useful information to have when the asteroid's orbit carries it so close to Earth. The surface-mapping phase will also allow scientists to determine the safest spot for OSIRIS-REX to perform the sampling part of its mission.

To collect a sample, OSIRIS-REX will deploy its TAGSAM, or Touch-And-Go Sample Acquisition Mechanism, which consists of a cylindrical sampler head attached to a 3m-long articulated robotic arm. When TAGSAM comes into contact with the asteroid's surface, nitrogen will be blasted into the head, causing particles to fly off. A screen inside the head acts like a vacuum bag, catching the dust and storing it in the outer walls of the cylinder. There is enough nitrogen for three attempts (each 'touch down' limited to five seconds to reduce the risk of collision with Bennu) to collect a minimum of 60g of surface material. With the sample collected, OSIRIS-REX will move away from Bennu, safely stow the head within the Sample Return Capsule and begin the wait for a window to return home.

## It'll be a long wait

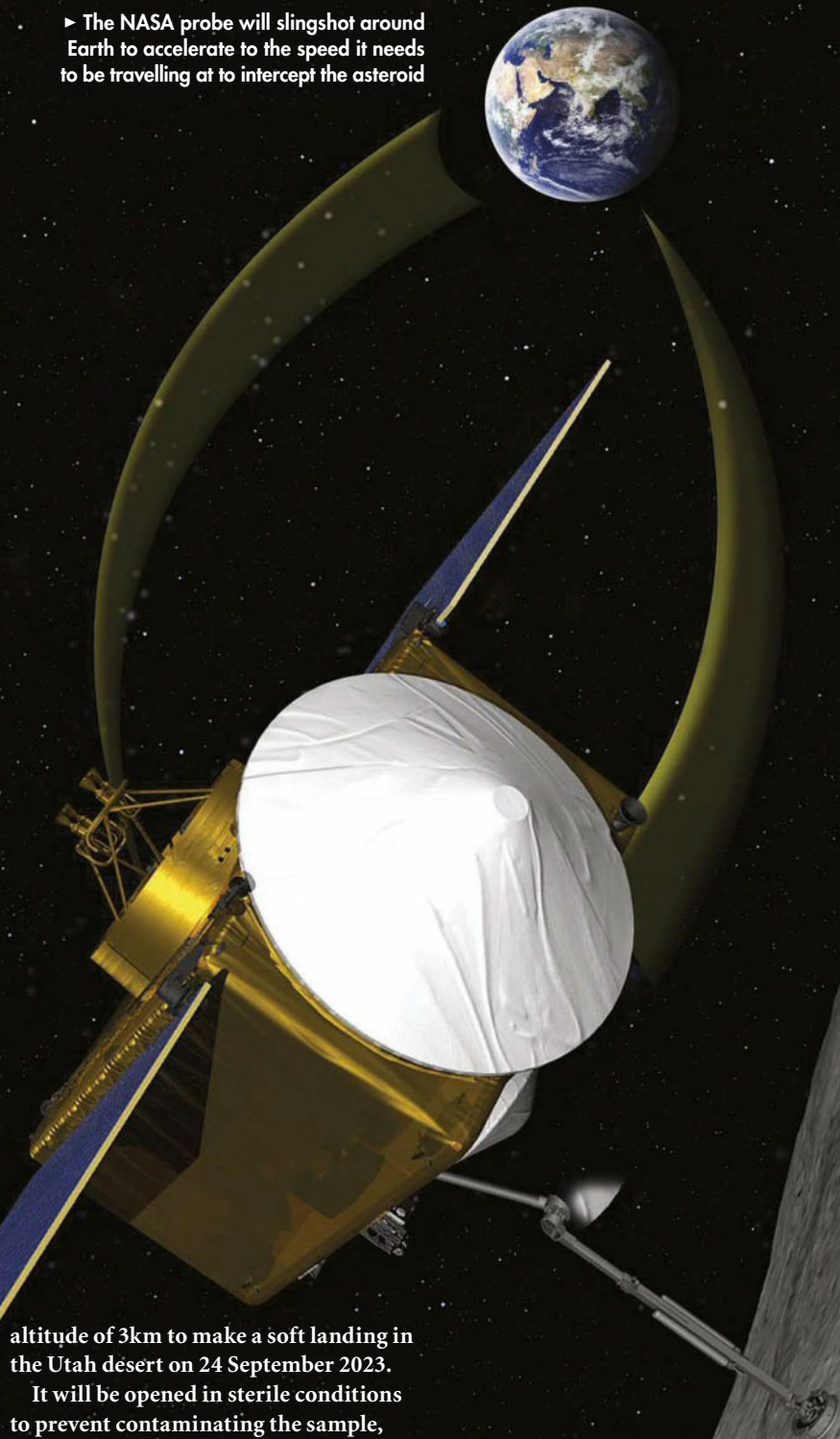
Bennu's elliptical trajectory means that the distance between the asteroid and Earth varies from about 100,000km to 1.9 million km, so OSIRIS-REX will have to wait several years for Bennu to pass close enough to Earth to begin its return journey.

Once the return window opens in March 2021, OSIRIS-REX will fire its main engines and depart on a trajectory that will intercept the orbit of Earth in September 2023 – at which

point the return capsule will be jettisoned and OSIRIS-REX will move into a stable orbit around the Sun.

The capsule will enter Earth's atmosphere at a speed of just under 45,000km/h, relying on its heat shield to remove 99 per cent of its kinetic energy, before deploying a parachute at an

► The NASA probe will slingshot around Earth to accelerate to the speed it needs to be travelling at to intercept the asteroid



altitude of 3km to make a soft landing in the Utah desert on 24 September 2023.

It will be opened in sterile conditions to prevent contaminating the sample, which will be analysed down to the atomic level to determine Bennu's composition and to identify the presence of any organic compounds, such as amino acids and sugars – the building blocks of life. **S**



## ABOUT THE WRITER

Ben Gilliland is a science writer, illustrator and author of *How To Build A Universe: From the Big Bang to the End of the Universe*.

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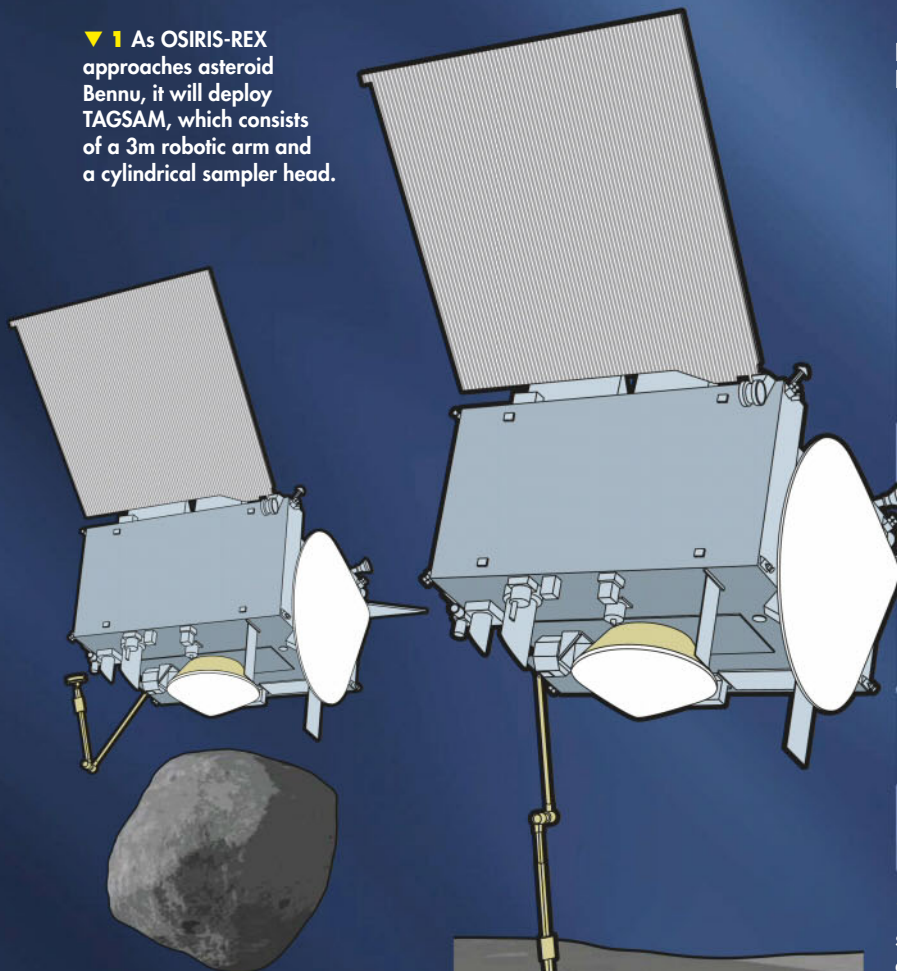
Turn the page for an infographic  
of the sample-collection phase  
of the OSIRIS-REX mission



# OSIRIS-REX SAMPLE-COLLECTION PHASE

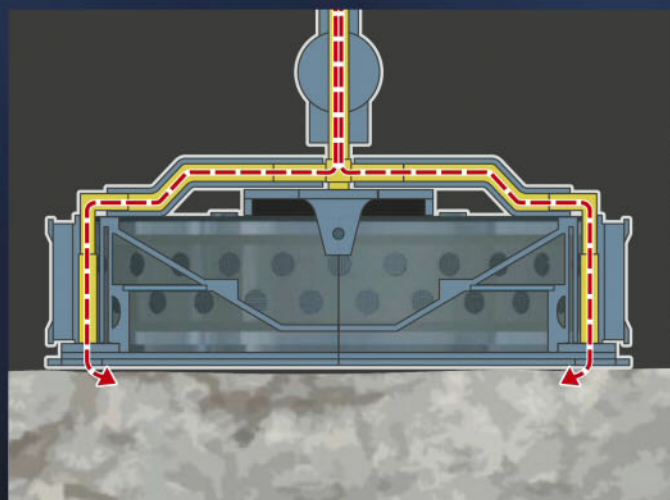
How the spacecraft will grab pieces of asteroid Bennu for us to study

▼ 1 As OSIRIS-REX approaches asteroid Bennu, it will deploy TAGSAM, which consists of a 3m robotic arm and a cylindrical sampler head.

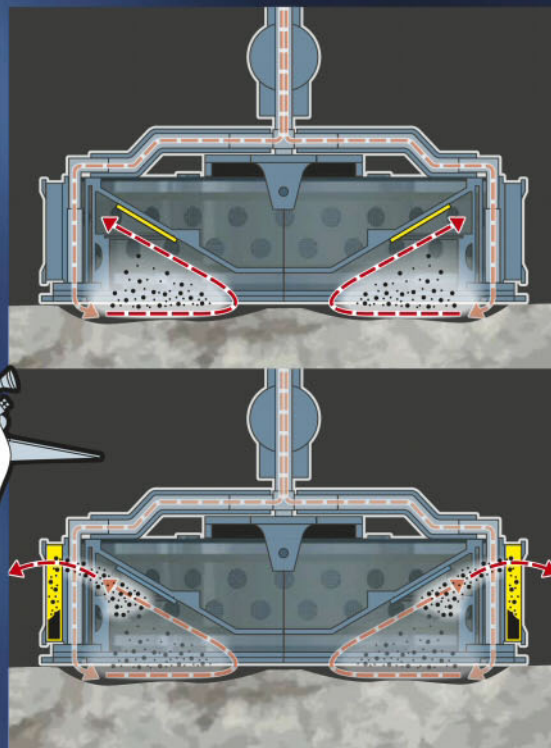


▼ 2 When the head makes contact with the asteroid's surface it will release a burst of nitrogen gas.

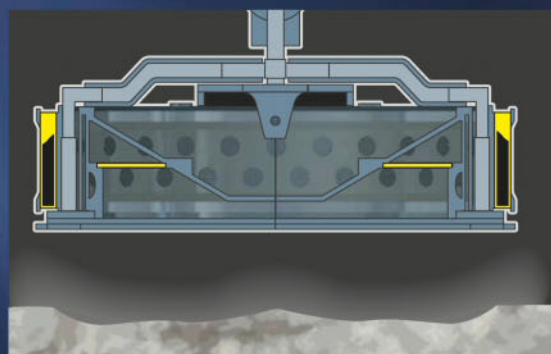
▼ 3 This will cause loose surface material to be stirred up into the cylinder, where a mylar flap will open to allow the material into the sampler head.



▼ 4 Sample material will be directed into a collector located in the outer walls of the cylinder. Nitrogen gas will be vented from the cylinder.



▼ 5 After five seconds, the head will lift away from the surface. OSIRIS-REX carries enough nitrogen to make three attempts to collect a minimum 60g of asteroid material. A surface contact pad will also collect fine grains.



▼ 6 Collection complete, OSIRIS-REX will move away from Bennu and stow the TAGSAM head in a Sample Return Capsule for the journey home.

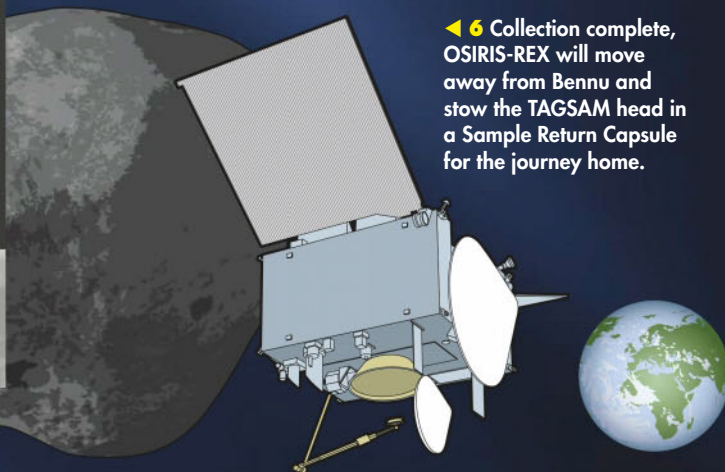


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# Tricks of the trade

## INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

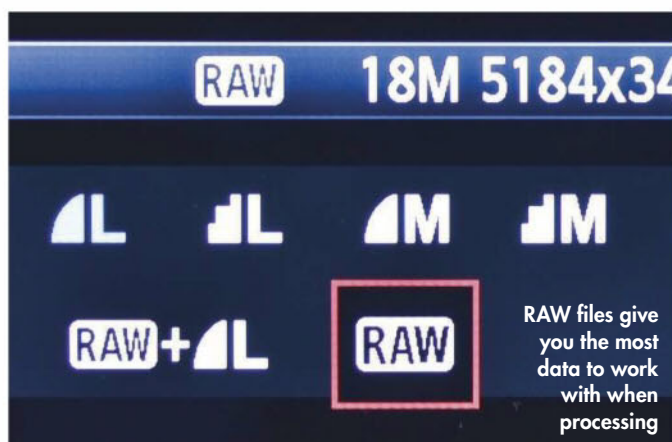
The darkening nights mean now is a great time to start taking images for the 2017 Astronomy Photographer of the Year competition. The winners of the 2016 contest will be announced this month. [www.rmg.co.uk/astrophoto](http://www.rmg.co.uk/astrophoto)

As August gives way to September, many imagers in the northern hemisphere begin planning the images they hope to shoot during the approaching long nights. But if you're just starting out, the methods – and frequently the vocabulary – of astrophotography can be as opaque as the darkest Milky Way dust lanes. In this article we're going to tackle that by providing some tips for budding imagers, as well as summarising some of the techniques and processes you might encounter.

Astrophotographer **Will Gater** provides some hints and tips for imagers just starting out in the world of night-sky photography







## SHOOT RAW FOR NIGHTSCAPES

DSLRs (Digital Single Lens Reflex cameras) are a popular choice for astrophotography beginners and experts alike, especially when it comes to nightscape photography – such as wide field shots of the Milky Way over a landscape, planetary groupings and star trails. One trap that beginners often fall into, however, is that they don't shoot in RAW mode, which preserves as much data as possible – instead leaving the camera to record compressed JPEG files. The merits of shooting either RAW or JPEG for deep-sky astrophotography are often hotly debated, but in our opinion RAW is absolutely the way to go when capturing nightscapes. For one thing, you have more to work with when it comes to using processing software, such as Photoshop – this is particularly important if you're dealing with the dark, shadowed areas often found in nightscape foregrounds. And if you end up wanting to come back to reprocess an image at a later date you have the highest-quality data with which you can start again.

## WHAT IS AUTOGUIDING? ▷

To take unblurred, long-exposure images of celestial objects you need a motorised mount to track the motion of the sky. If correctly polar aligned, a good mount should allow exposures of a few minutes without any substantial trailing of the stars due to tracking imperfections. But for much longer exposures, of the kind you need for imaging faint galaxies and nebulae, you need some way of ironing out any blips in the accuracy of the mount's tracking. This is what the process of 'autoguiding' achieves. Autoguiding commonly involves an additional camera and telescope attached to the mount – their job it is to monitor a single star with the help of computer software. If that star deviates in position while the mount is tracking, the software sends a 'guiding' correction to the mount. The result: long exposures captured by the main scope and camera show an accurately tracked view with perfect, round stars.

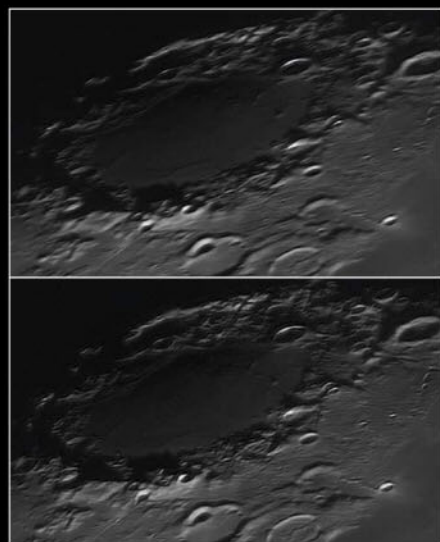


A guiding scope and camera will prevent stars from trailing in long-exposure shots

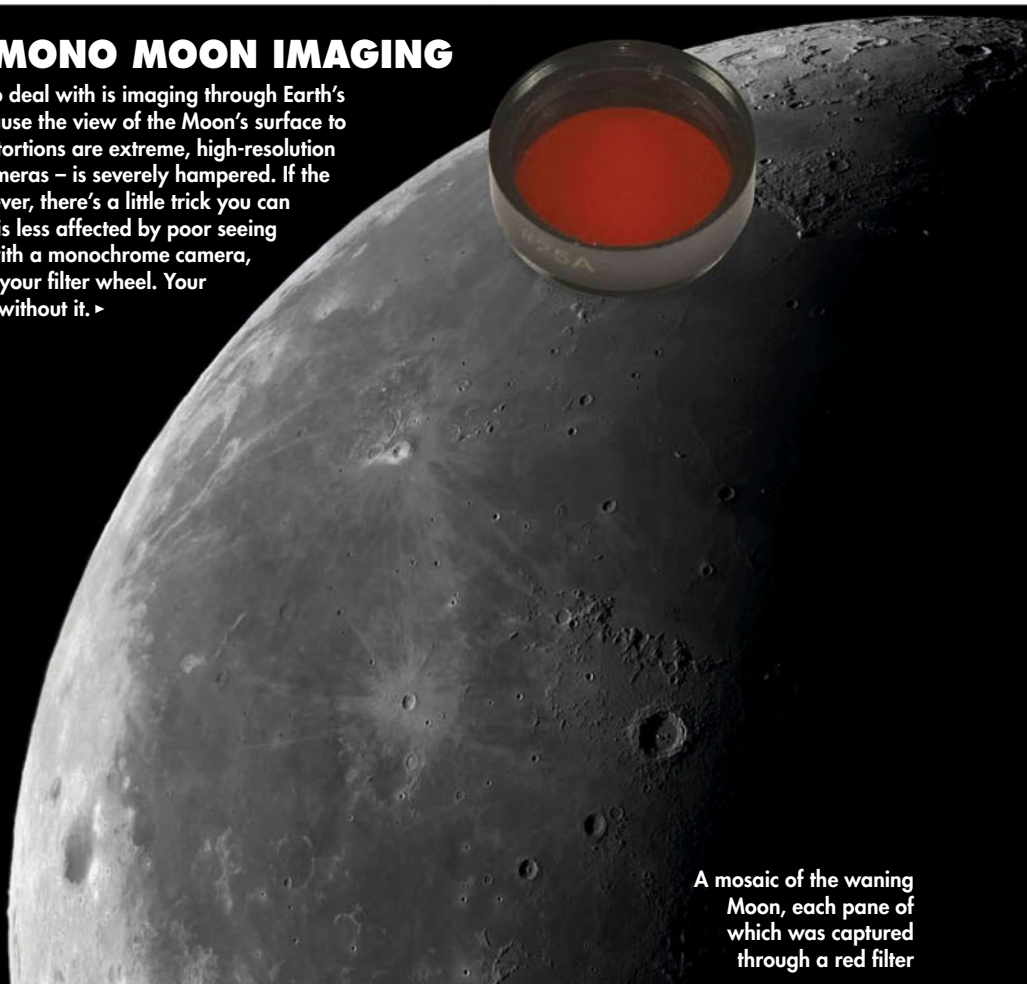
PAUL WHITFIELD, STEVE MARSH, WILL GATER X 2

## USE A RED FILTER FOR MONO MOON IMAGING

One of the things that every lunar imager has to deal with is imaging through Earth's atmosphere, as the undulations within the air cause the view of the Moon's surface to shimmer and wobble. On nights when these distortions are extreme, high-resolution imaging – with webcams or high-frame-rate cameras – is severely hampered. If the 'seeing' conditions are only slightly ropery, however, there's a little trick you can use to improve your resulting images. Red light is less affected by poor seeing than other wavelengths. So, if you're imaging with a monochrome camera, pop a red filter on the camera's nosepiece or in your filter wheel. Your final images should be sharper than if you shot without it. ▶



▲ Crater Grimaldi, captured with a luminance filter (top) and with a red one (bottom)



A mosaic of the waning Moon, each pane of which was captured through a red filter



## ▽ THE BEAUTY OF BAHTINOVS

If there's one thing that will dramatically let down even the most beautifully composed or captured astro image, it's failing to properly focus the shot. Thankfully, achieving perfect focus has become much easier in recent years. Part of this is due to the increased prevalence of live-preview screens on DSLRs. But when imaging with a telescope there's also another, relatively inexpensive, tool available that can help you to accurately focus every time. A Bahtinov mask, placed over the aperture of the telescope, produces a special diffraction pattern that changes as you adjust the focus. When the 'middle' diffraction spike is centred precisely the image is in perfect focus. Take the mask off and you're ready to start imaging.



The view through a Bahtinov mask before focusing (top) and after (bottom)



Set your scope up outside and leave it to cool down to prevent air currents in the tube

## △ COOL YOUR SCOPE

If you've ever tried observing the Moon or a planet through a telescope out of a window in a warm room, you'll know how air currents can produce horrendously wobbly views. A similar effect occurs if your telescope doesn't cool down before you use it for lunar or planetary imaging. If you take the warm telescope straight out, air currents within the scope itself will degrade the quality of your pictures. In an ideal world, leave your scope outside for at least an hour or so before imaging.

## ▷ LEARN HOW TO TAKE FLATS

If you're serious about pulling out faint detail in your deep-sky images there's one form of image calibration that's really worth learning: flat fielding. Flat fields can help combat the effects of vignetting, where the edge of image appears shadowed, as well as the dark blotches that often appear in the backgrounds of deep images as a result of dust on the camera sensor or in your equipment's optics. To take a crude flat field, cover your telescope's main aperture with some clean, white cloth – we use a pillowcase – and evenly illuminate the material with a torch. Then capture several exposures, taking care not to overexpose them. These can then be loaded into processing software to calibrate your data.

Securing a pillowcase over the end of your scope can deliver basic flat fields





## GET SHARP FOREGROUNDS IN LONG-EXPOSURE NIGHTSCAPES

When shooting nightscapes with a tracking mount, one problem that crops up is the loss of foreground detail. As the camera tracks the sky,

the foreground landscape becomes blurred while the stars remain sharp. Here's a simple four-step trick to get round that issue.

### STEP 1

First capture your long-exposure nightscape shot as normal. The following technique works best with relatively short focal length, wide-field nightscapes (say, less than 50mm) and with exposures of less than a minute or so – any longer (in both lens focal length and exposure) and creating a 'natural' composition may become challenging.



### STEP 2

Immediately after the long exposure has finished, take a much shorter exposure (lasting for seconds rather than minutes) to capture the foreground unblurred. This may mean you have to use high ISO values and open the lens right up to pick up the horizon clearly.



### STEP 3

Next load your long-exposure of the sky and the shorter one preserving foreground detail into a layer-based image processing program (such as Photoshop). Process your long-exposure image as you would normally and, where possible, try to match the processing of the sharp-foreground image with that of the long exposure.

### STEP 4

Finally, using a selection tool, select the landscape in the sharp-foreground shot. Apply a small feather to the selection and then copy and paste that foreground into your long-exposure image, matching up the features in the landscape. Once you have it in place, merge the layers and make final tweaks as necessary.



## STOP DOWN THE LENS TO REDUCE ABERRATIONS ▸

A great deal of astrophotography is about collecting as much celestial light as possible. When shooting with a DSLR and camera lens it's tempting, therefore, to open the lens right up by setting it to its widest aperture. In practice, though, using the full aperture of the lens can create problems. In most lenses doing this will cause vignetting and a noticeable distortion of the stars in the corners of the image. A better tactic is to compromise by 'stopping down' the lens to a smaller aperture and shooting at a higher ISO, which can be more easily dealt with in post-processing. Even better, stop the lens down and use a tracking mount to take a longer exposure. ▶

F/1.8 INSET

F/1.8 (WIDE OPEN)

F/4 INSET

F/4 (STOPPED DOWN)

Vignetting is greatly reduced after stopping down; star shapes are better too



Tweaking the colours of an image can completely alter your perception of the night sky

## WATCH YOUR BACKGROUNDS

Perhaps the greatest challenge to any astrophotographer who hopes to faithfully render the night sky in their images is balancing colour within a picture. For nightscape photography the list of light sources that can cause annoying colour gradients in a shot is long: from the various flavours of light pollution to natural phenomena like airglow. Sometimes these cannot be completely processed out, and in the case of airglow you may wish to record it as part of the nightscape anyway.

Either way, take care not to introduce unnatural colour casts to your background sky when attempting to tackle them in processing. If you need to tweak the colour balance of your images there are several ways you can do it. One approach is to adjust the 'Levels' sliders of individual colour channels in processing programs, like Photoshop. Some software packages also have tools that will attempt to do it automatically.



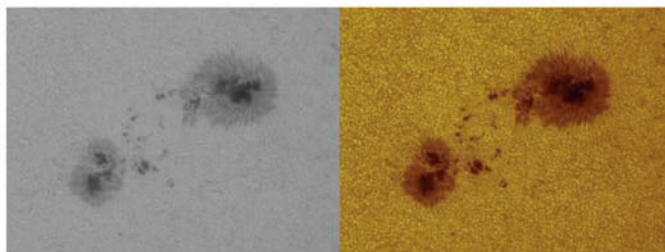
Intervalometers often double as remote shutter release cables

## △ INVEST IN AN INTERVALOMETER

If you're starting out in DSLR astrophotography one of the most useful tools you can have in your camera bag is an intervalometer. These handy, programmable devices plug into the camera – which will typically be set in 'B' or 'bulb' mode to allow the shutter to be left open for long periods – and can be used to fire the shutter a specified number of times, at a set interval and with an exposure length of your choosing. They are invaluable for when you don't want to manually fire the shutter on every exposure yourself, for example when shooting star trails, meteors or a lengthy series of long exposures. Usually they double as a manual remote release too.

## ▽ CONSIDER ADDING COLOUR TO MONO SOLAR SHOTS

Solar imaging, using a telescope fitted with a certified solar filter, can produce extraordinary images of our star. What you might not know, however, is that many if not all of the top solar imagers are using monochrome high-frame-rate CCD cameras to capture their pictures. How then do they produce vibrant colour images of the Sun? The answer is that artificial colour is added later, during processing. One of the easiest ways to turn a monochrome image yellow/orange is to adjust the levels sliders of the individual colour channels in a program such as Photoshop. In the 'Levels' tab, bring the right 'output level' arrow of the blue channel to the left – this should turn the image a greenish-yellow hue. Then move to the 'input levels' of the green channel and bring the middle and right slider towards each other until you've got a yellow-orange colour you're happy with.



▲ The monochrome original of a sunspot group on our star (left) and the same image after the colours had been edited (right)



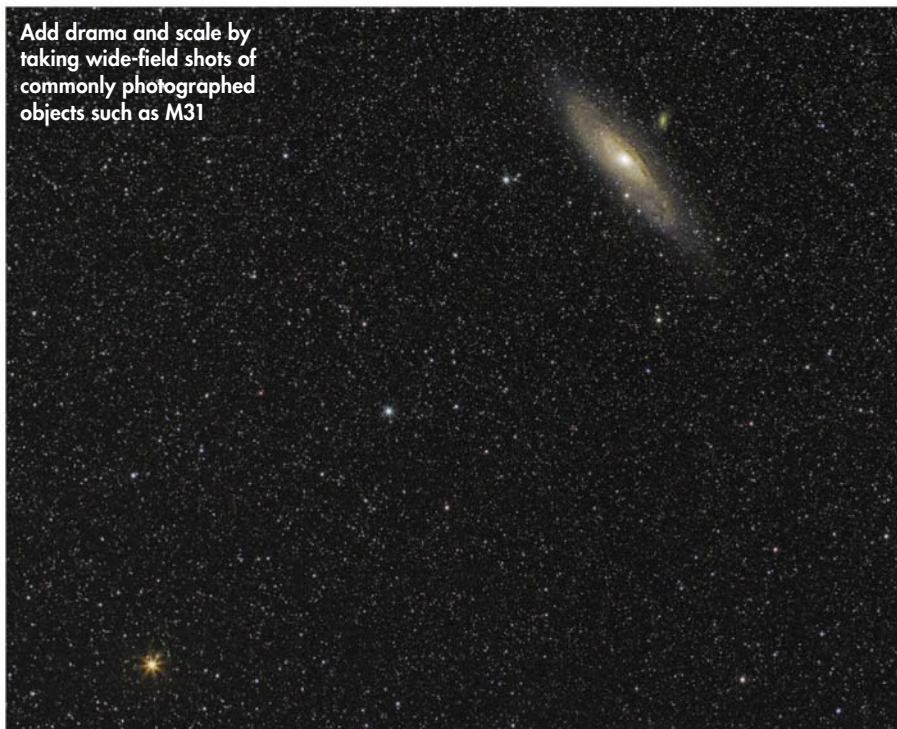
## ▽ KEEP DEW OFF YOUR OPTICS

On a clear night, dew forming on your optics can ruin your astrophotos. Exposed front lenses of refracting telescopes, corrector plates of Schmidt-Cassegrains and DSLR lenses are most susceptible to dew formation. A dew shield mounted on the front of a scope can help slow the cooling of its optics and so hinder dew formation, but often it won't be enough for long imaging sessions. It's therefore worth investing in a dew heater system, which will allow you to make use of clear skies.



▲ A dew heater is the best way to keep condensation at bay on your scope

Add drama and scale by taking wide-field shots of commonly photographed objects such as M31



## △ SHOOT FAMILIAR OBJECTS A DIFFERENT WAY

One thing that many imagers find after several years of taking photos of the night sky is that certain targets – usually deep sky objects such as nebulae and galaxies – always look the same from year to year. After a while you may find that there are only so many times you can shoot the same object and improve upon your last image of it. If you find that's becoming the case, it may be worth stepping back and looking at how else you could photograph it. Many seemingly isolated but bright nebulae, for example, are part of much larger regions of nebulosity which could make stunning subjects for a multi-pane mosaic. And even individual bright galaxies can look really striking when placed in the wider context of their surrounding star fields, either with a mosaic or by using, for example, a telephoto camera lens rather than a longer focal length telescope.

## BANISH CLEAR SKY GUILT

As every astrophotographer soon finds out, clear skies are not a regular occurrence in the UK. This can cause a feeling of guilt when there finally is a beautifully clear evening and you're just not interested in lugging out all the kit. Take it from us, this is perfectly normal and many imagers have felt the same at one time or another. If you still want to do something astrophotography-related, why not revisit and reprocess old data – you may be surprised at what is in there. **S**



### ABOUT THE WRITER

Will Gater is an astronomy journalist, author of several books and an astrophotographer. Follow him on Twitter: @willgater

Even clear evenings spent in front of the TV can help your astronomical adventure – consider catching up with *The Sky at Night* on BBC Four







## The Guide

### Understanding comets

With Elizabeth Pearson

The least predictable Solar System visitors can be one of its great highlights



Some comets can become brighter than the planets; this one is C/2006 P1 McNaught, which peaked at around mag. -5.5

such as Halley's Comet, have an orbit that only lasts a few years or decades, and so are called short-period comets. Others, called long-period comets, travel much farther into deep space, taking thousands of years to complete an orbit.

For most of these orbits, the nucleus remains an inert lump of ice, but this changes as the comet nears perihelion, its closest approach to the Sun. When close enough, the solar radiation heats the surface, causing the volatile components to boil. As the gas escapes into deep space it lifts off dust, creating a shroud that can stretch out over 50,000km around it – the coma.

### Comet versus Sun

As the comet gets closer to the Sun, this envelope begins to feel the solar influence even more acutely, as its wind and magnetic field sweep the dust and gas out into a huge tail. This can extend for millions of kilometres, spanning huge swathes of the Solar System. Some of the tail's debris is left behind in its orbit to form a meteoroid stream. Several of these cross the Earth's orbit, and when we pass through them every year, we see the debris burning up in the atmosphere as a meteor shower.

For most comets, these close encounters with the Sun do little more harm than melting another layer off the nucleus. However, sometimes comets get too close, and the stresses caused by the intense heat and gravity cause them to break apart, as happened in 2013 with C/2012 S1 ISON.

Sunlight reflecting off the coma and tail causes these celestial visitors to glow in the night, making them an ever-popular target for astronomers. Unlike the annual meteor showers their passing can create, comets are a much more transient phenomena adhering to a timetable all of their own. However, every year there are a handful of comets that can be seen with the aid of a small telescope. Websites such as International Comet Quarterly ([www.icq.eps.harvard.edu/cometobs.html](http://www.icq.eps.harvard.edu/cometobs.html)) and the

**W**anderers of the Solar System, comets can rank among the most spectacular of astronomical sights when they appear in our skies. These mysterious visitors never fail to capture imaginations when they pass by, and after years of careful observations astronomers have coaxed out the secrets hidden by their glow.

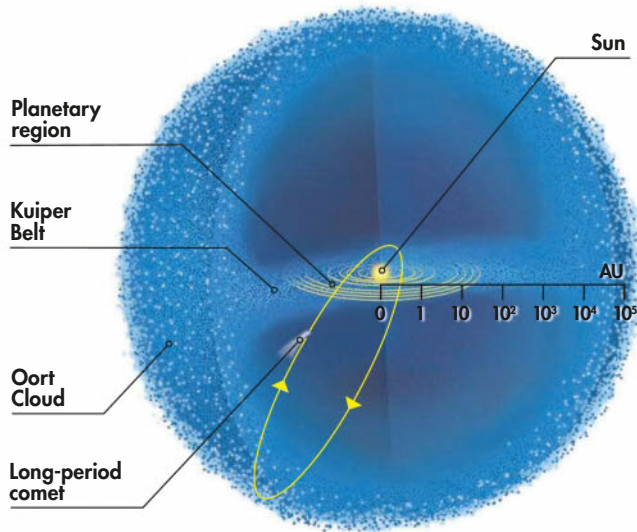
The heart of a comet is its nucleus, a core of ice laced with rock and dust, a few kilometres wide. Though sometimes called a 'dirty snowball', the ice found on comets is far more exotic than that on Earth.

When the Rosetta spacecraft reached 67P/Churyumov-Gerasimenko in 2014 it performed the first in-situ analysis of a comet's nucleus, finding not only water-ice, but also carbon dioxide and monoxide, as well as traces of ammonia, methane and methanol. These highly volatile compounds are usually found as a gas or liquid on Earth, but the frigid depths of space have frozen them to ice as hard as rock.

These snowballs travel in huge elliptical orbits, briefly visiting the inner Solar System at one end before travelling billions of kilometres to the outer regions. Some,



## WHERE DO THEY COME FROM?



After the planets formed, the material left over in the outer Solar System coalesced into a great many icy bodies. These organised themselves into two regions. The inner of these is a ring between 4.5 and 7.4 billion km, known as the Kuiper Belt. It's thought that short-period comets come from this region. Far beyond this, surrounding the entire Solar System, is a much larger cloud that is thought to stretch out 3.2 lightyears called the Oort Cloud.

British Astronomical Association's Comet Section ([www.ast.cam.ac.uk/~jds](http://www.ast.cam.ac.uk/~jds)) list all of the comets that are currently active and visible with an amateur telescope, and where they might be found.

Even if we know when a comet is likely to appear and the path it will take, no one can guess what it will behave like once it approaches the inner Solar System. A comet could pass so close to the Sun that experts are sure it will be a spectacular view, only for it to break apart during perihelion, or give little more than a fizz of a tail. However, once in a decade or so there is a comet that

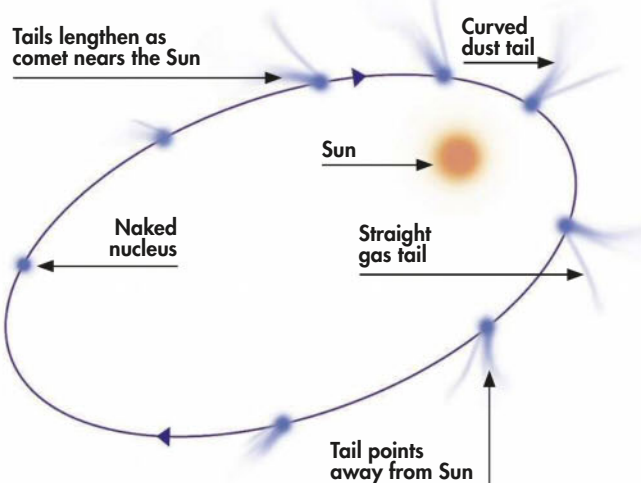
passes close enough to Earth and is bright enough to be seen with the naked eye. When one of these is truly exceptional it may be bestowed the moniker of 'Great Comet'; an apparition so magnificent it is remembered for centuries (or even millennia) to come.

Though in the past comets used to hold a bad name, as the portents of death and war, now these capricious visitors are a highlight for anyone lucky enough to see one as it passes by. **S**

Elizabeth Pearson is *BBC Sky at Night Magazine's* news editor

## CHASING THE TAIL

The most alluring part of a comet is surely its huge tail, but what is not always obvious is that there are two. The most apparent is the dust tail, which the solar wind sweeps out in an arc. However, the magnetic field captures the gas, pulling it away to form a much fainter second tail. Regardless of where the comet is in its orbit, the tails will point away from the Sun, rather than streaming behind as is often believed.



## FIVE FAMOUS COMETS

### HALE-BOPP



**Closest approach:** 136 million km.  
**Period:** 2,520 to 2,533 years.  
Naked eye visible for a record 18 months in 1996 and 1997, Hale Bopp captured the public interest the world over.

### 67P/CHURYUMOV-GERASIMENKO



**Closest approach:** 186 million km.  
**Period:** 6.4 years.  
The target of the Rosetta mission, which studied the comet from orbit and sent the Philae lander to its surface.

### GREAT DAYLIGHT COMET



**Closest approach:** 19 million km.  
**Period:** 57,300 years.  
Spotted in January 1910, this comet quickly grew in brightness until it outshone even Venus.

### HALLEY'S COMET



**Closest approach:** 88 million km.  
**Period:** 75.3 years.  
This regular visitor was observed as early as 240 BC. It is often visible to the naked eye.

### IKEYA-SEKI



**Closest approach:** 450,000 km.  
**Period:** 876.7 years.  
In 1965, Ikeya-Seki's close pass of the Sun caused it to become one of the brightest comets of the past millennia.



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With Mark Parrish

# How to Build an advanced accessories case

A highly customisable container for all your astro gear



The completed case provides robust storage for your delicate accessories



## TOOLS AND MATERIALS

### TOOLS

Tenon saw or equivalent, drill with bits to suit, wood screws and eyepieces, sandpaper, clamps, small hammer, screwdriver.

### MATERIALS

Two 2.4m lengths of 44x15mm softwood and two 2.4m lengths of 25x15mm softwood per box layer, 6mm plywood for the sides and bases of each layer.

### SUNDRIES

Cabinet fasteners with small screws (a pair for each layer), 15mm panel pins. PVA wood glue, eyelets and bag strap or handles, 30mm M6 nylon screws, 40mm M6 bolts and wingnuts, masking tape, string, LED battery lamp.

### FINISH

Fine sandpaper, exterior quality gloss paint or varnish, red spray for lamp.

**W**hatever stage you have reached in astronomy, or whatever interests you have, you will inevitably accrue a lot of precious equipment. This needs to be stored carefully, but also transported to dark sites in an orderly way so you can make effective use of your time – which is why this month's project is on how you can make your own accessories case and customise it to suit your particular needs.

Our basic design has space for eyepieces in the main layer with a lid, which doubles up as a tray you can use for a star chart. Additional layers can be added to the stacking design to house other items, such as cameras, filters, cables and tools.

One of our main objectives was to create a design that didn't require any of the tricky woodwork joints usually associated with this kind of project. In its place we have devised a neat, overlapping corner

method, which just requires some accurate sawing. You might find a timber supplier or friendly DIY enthusiast with a machine to do a lot of the cutting work for you, but with a little care it is possible for anyone to make strong boxes using our technique. The construction is then a simple matter of pinning and gluing together.

### You can even add a light

We also added an inexpensive LED battery lamp (found in many DIY superstores). If you disassemble it you can spray the lens red and mount it on a moveable arm made from plywood that folds away inside the case to form a kind of angle-poise lamp. This makes locating that elusive eyepiece much easier in the dark! The upturned lid forms a tray – useful for temporarily placing lens caps and small items on, but which can also form a small chart table. We designed it to accommodate an A4 sheet, so we could use printed charts. The

lamp can be positioned so that it illuminates the chart or box below and if the lamp unit is affixed to the plywood arm with a Velcro patch you could use it as a removable torch if you need light elsewhere.

The eyepieces are held in two internal timber shelves. These are drilled to suit the eyepieces and we used non-marking nylon screws to hold them in place. Each shelf is glued in place, supported on two small rectangular off-cuts of plywood, which ▶





▲ The layers stack for easy storage, and you can take only the ones you need out observing

► are stuck to the inside of the box below either end. We lined the bottom of our case with felt, but there is room here for a rack of filters or other small accessories such as pencils and notebooks if you wanted to improvise.

Each box has a raised internal lip around the top edge and this fits inside a corresponding recess below the base of the box above. This means the boxes can be stacked and locked together to form a modular case of any height. You could keep all your accessories in one place at home, but perhaps only take selective layers out for a night's observing. You could even add dividers into individual layers.

A shoulder strap was added to our upper layer to make carrying easy, but handles could be added or even small casters if your stack of cases becomes large or you decide to scale up the design. It is also possible to add some padding to the lid to create a seat if you often find yourself waiting for the clouds to clear.

We hope that you feel inspired to give this project a try. You might decide to stick to the online plans for your first layer, but once you have mastered the basic principle, it is easy to add some more layers with varying heights or devise your own modifications as your interests in astronomy grow and evolve. We hope you enjoy making this project and we look forward to seeing your own versions if you wish to send us your images. 📧

Mark Parrish is a consummate craftsman who loves making astro accessories

**YOUR BONUS CONTENT**

Download the plans needed to complete this project

## STEP-BY-STEP GUIDE



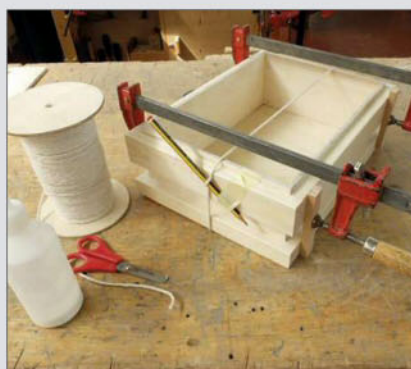
### STEP 1

Use the dimensions on the printable plans in this month's Bonus Content to mark out the timber to size and clamp a straight piece of wood to each part and use this as a guide for the saw. A timber merchant might be able to cut your wood for you.



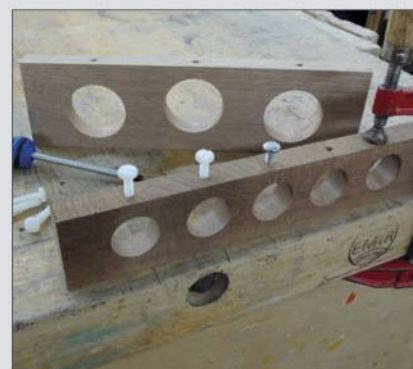
### STEP 2

Use PVA glue and pins to join the softwood strips to each plywood side. We made a spacer from offcuts of wood to achieve the correct overhangs and lip sizes. Check the parts fit to make each box layer before the glue dries.



### STEP 3

The main sections can now be glued together. PVA wood glue is strong but you need to put pressure on it while it dries. If you don't have long clamps, make 'tourniquet' clamps from string and a pencil, as above. Fit the base at the same time to keep it square.



### STEP 4

Drill 1.25-inch or 2-inch holes for your eyepieces in two lengths of timber, pre-cut to fit inside the case. Drilled 5.5mm holes can be threaded by screwing in an M6 metal screw. When this is removed a nylon screw is substituted in.



### STEP 5

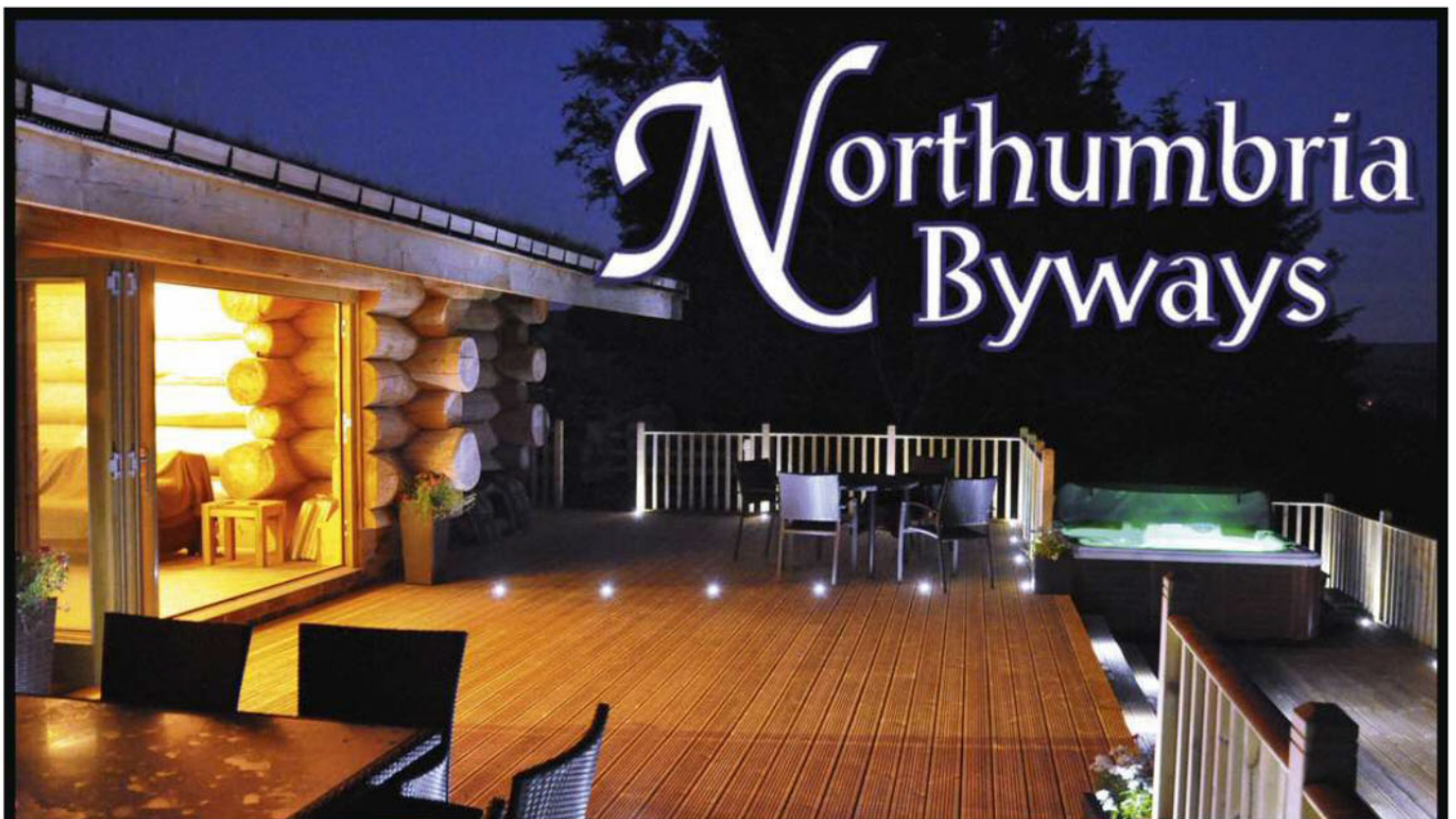
An LED lamp can be mounted on an arm made from two strips of plywood. Cut and drill these while taped together so they are identical. The arms are joined to two timber blocks, which attach to the lamp and case respectively. M6 screws and wingnuts provide some friction.



### STEP 6

Use small screws to attach the fasteners to your accessory case. Dividers can be added to suit your requirements. Remove all fasteners, rub with fine sandpaper and paint or varnish. Reassemble and line with felt if required.





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With **Jamen Percy**

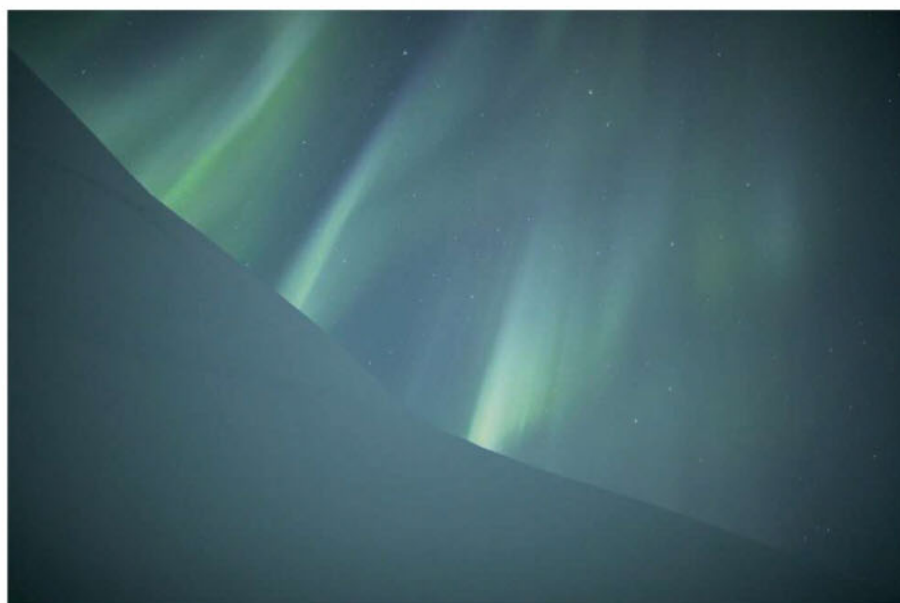
# Image PROCESSING

INSIGHT  
ASTRONOMY  
PHOTOGRAPHER  
OF THE YEAR

Expert advice from  
2015's aurora  
category winner

## An IAPY winner's take on editing aurora images

Learn the secrets of post processing shots of the Northern Lights



▲ Jamen's shot straight from the camera – a foreground is useful for balancing colour later on

**M**y IAPY 2015-winning aurora image 'Silk Skies' was taken in only four seconds, but took eight years of practice to get right. Only a small amount of post-production was actually applied to the image – but the adjustments that I made were essential and I apply them to all my aurora images.

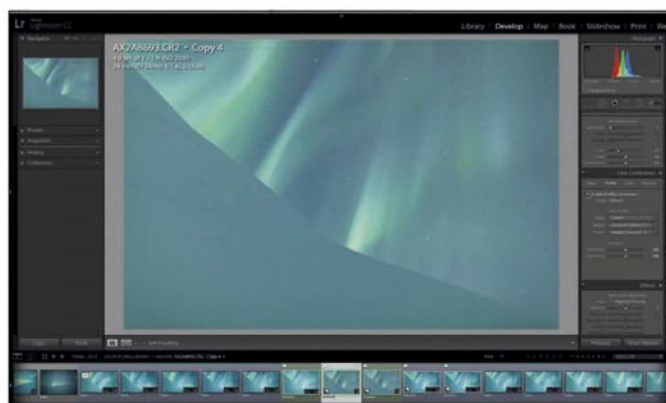
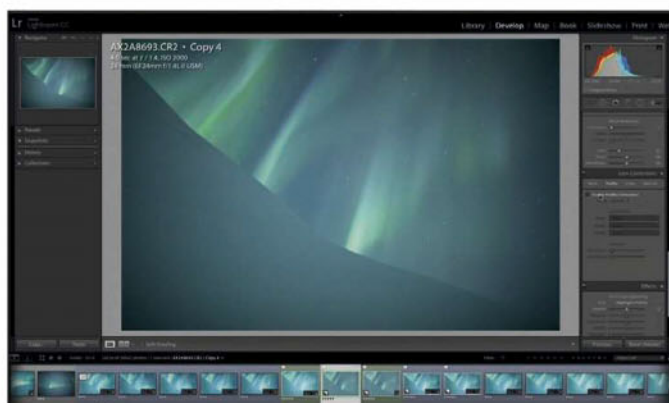
My adjustments are made in the RAW format in Adobe Lightroom. I always start with **Lens Corrections**. To do this, click on the **Develop** tab and scroll down to Lens Corrections, then click **Enable Profile Corrections**. This is great because it has all of the lens's discrepancies built-in, so it counters vignetting and distortion perfectly according to the lens used.

After that click the **Colour** tab inside the Lens Corrections module and then the **Remove Chromatic Aberration** box. This is really important for aurora photographs as there is often a bad red/blue fringing around contrasted edges, particularly the stars. Chromatic aberration varies in severity between lenses and the f/stop used. If you stop your lens down it will usually reduce it, but of course you can't with aurora photography, as you need as much light as you can entering the lens. This is why I always stick to high-quality lenses.

Next I adjust the detail. For aurora photos I slightly increase the sharpness. Most DSLRs by default shoot a little soft, but this is intended – it is anticipated that you adjust your own sharpening in post processing. I do this just to bring out the stars and any foreground detail. It will have no effect on the soft shapes of the aurora. In addition I add noise reduction – not a lot, but just enough to smooth some of that harsh grain.

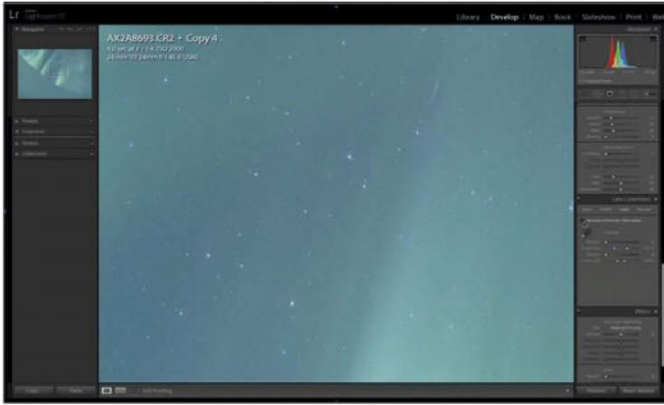
### The finer points

Once the core corrections are done I tweak up the exposure to get the perfect brightness, ramp up the contrast to make the image really pop and raise the clarity



▲ The image was edited entirely in Adobe Lightroom; here it is before (left) and after (right) Lens Corrections have been applied





▲ Stars offer suffer chromatic aberration in aurora pics – fixing this is vital

a small amount. This enhances the mid-tone detail, which often includes auroral beams. I never raise the saturation; if anything I would bring it down as altering the contrast tends to fire up the colours enough. If you increase the saturation too much, the image becomes ‘overcooked’ and can look fake. It’s a common error and something to avoid. As a nature photographer – which as an astro imager, you are – you should always represent the natural world accurately.

The final tweak I make is the white balance, which can be tricky. It is

imperative that you represent the true colours as you saw them or you risk being discredited. It’s good to have foreground objects in your picture as you (and the viewer) can use these as a colour reference. Getting the correct white balance can only be done by memory and by eye, which is why I try to process my aurora images as soon as I get back to base, as the colours are still shimmering fresh in my mind.

If you are struggling to find the correct white balance, a good starting point is to use the White Balance Eye Dropper tool. First click on the tool (it is in the right



▲ Before and after noise reduction to smooth out sky graininess

panel of **Develop** tab) then click on part of the scene that is white and influenced by the light of the aurora. The image will usually go too warm. Roll in a little bit more blue with the slider above the eye dropper, then a bit of green and I find in most occasions this is close to what the moment was. This will always vary with the colour of the aurora, any light pollution or lunar glare, so there is no set-in-stone white balance setting. **S**

Jamen Percy’s ‘Silk Skies’ image won the Insight Astronomy Photographer of the Year 2015 aurora category



▲ The final processed image, which wowed the judges and won Jamen the aurora category at Insight Astronomy Photographer of the Year 2015





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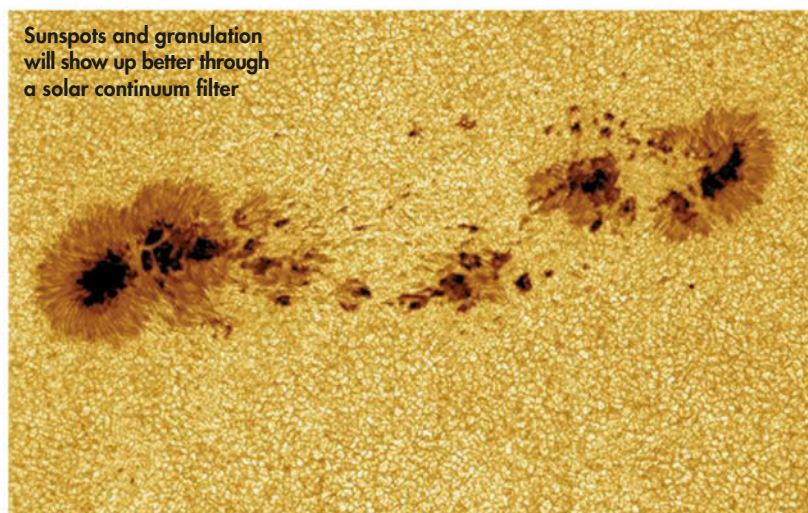




With **Steve Richards**

# Scope DOCTOR

Our resident equipment specialist cures your optical ailments and technical maladies



Sunspots and granulation will show up better through a solar continuum filter

**Will a hydrogen-alpha CCD filter help to enhance my views of the Sun through my 5-inch reflector? I'm currently using a Baader Astrozap white light filter.**

KIM RALLS

White light filters that fit over the front of your telescope provide a very safe way to observe our star, the sunspots on the Sun's photosphere in particular. The photosphere is the lowest layer of the Sun's visible atmosphere, the other two being the chromosphere and the corona.

Special telescopes designed specifically for observing the Sun use a sophisticated filter called an etalon to block all but a very narrow bandwidth of light centred on 656.3nm, which is the hydrogen-alpha (Ha) portion of the spectrum. Images of the Sun viewed through this type of filter show a strong red colour. Although we are talking about the same Ha here, the difference is in

the filter bandwidth. A typical etalon has a bandwidth of 0.7 Ångströms which is 0.07nm whereas a very narrow CCD Ha filter may have a bandwidth of around 3nm – 43 times wider.

Using a CCD Ha filter, designed for imaging nebulae, won't work for solar observing because the additional light either side of the central Ha portion will swamp the portion of the light that you do want to see.

There are filters that, used along with a white light filter, will increase the contrast of the view. A Wratten #58 or Baader Solar Continuum filter will allow you to view granulation and increased detail in sunspots. It is also worthwhile including an infrared-cut filter at the same time.

## STEVE'S TOP TIP

**What kind of thing should I write in my astronomy journal?**

Keeping a log of your stargazing sessions is great fun, not just for comparing with later observations but also for real astronomical research. Start by recording the date and time of your observations in UT, your location, object observed, telescope, eyepiece and any filters in use. With the fixed data recorded, you can now describe your observations in your own style – including brightness, perceived magnitude, seeing and transparency levels, light pollution, presence of the Moon and weather conditions. For the Moon, planets and comets, note the constellation in which they were viewed. Wherever possible, include a simple sketch.

**I want to upgrade my 25 and 10mm eyepieces for my Sky-Watcher SkyMax Maksutov-Cassegrain. Any suggestions?**

CHRIS LEWIS



▲ Original Sky-Watcher eyepieces (front) with Baader Hyperion equivalents behind

The eyepieces shipped with most telescopes are normally adequate to get you out and observing quickly, but they are without doubt the weak point in the system. However, the 25mm and

10mm focal lengths chosen by the manufacturer allow a wide range of objects to be observed.

Upgrading to better quality eyepieces would be very worthwhile for you as the SkyMax 127 telescope has excellent optics that you can put to good use. The advantages of upgrading would include better colour correction, field edge clarity and a more immersive, wider field of view.

The supplied Plössl eyepieces have an apparent field of view of 52°. The 1.25-inch visual back of your scope currently limits your choice to 1.25-inch alternatives, but suitable upgrade eyepieces would include 25mm and 8mm BST Explorers with an apparent field of 60° or 24mm and 10mm Baader Hyperions with an apparent field of 68°.

Steve Richards is a keen astro imager and an astronomy equipment expert

Email your queries to [scopedoctor@skyatnightmagazine.com](mailto:scopedoctor@skyatnightmagazine.com)





1<sup>st</sup>



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2<sup>nd</sup>



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3<sup>rd</sup>



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# Sky at Night MAGAZINE Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

## HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

- ★★★★★ Outstanding
- ★★★★☆ Very good
- ★★★★☆ Good
- ★★★★☆ Average
- ★★★★★ Poor/Avoid

90

The surprise performance of PrimaLuceLab's new doublet refractor, the AIRY APO120



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## This month's reviews



### First light

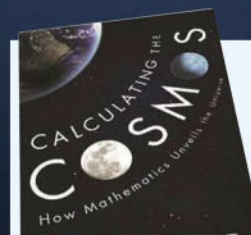
**90** PrimaLuceLab AIRY APO120 doublet refractor



**94** Celestron Skyris 236C Solar System camera



**98** QHYCCD PoleMaster electronic polarscope



### Books

**102** We rate four of the latest astronomy titles



### Gear

**104** Including this AYO altaz mount

Find out more about how we review equipment at [www.skyatnightmagazine.com/scoring-categories](http://www.skyatnightmagazine.com/scoring-categories)



# FIRST light

See an interactive 360° model of this telescope at [www.skyatnightmagazine.com/airy120apo](http://www.skyatnightmagazine.com/airy120apo)



## PrimaLuceLab AIRY APO120 refractor

A surprising scope with a doublet that offers astounding and aberration-free views

WORDS: TIM JARDINE

### VITAL STATS

- **Price** £2,268
- **Optics** Multicoated apochromatic doublet
- **Aperture** 120mm (4.72 inches)
- **Focal length** 900mm (f/7.5)
- **Focuser** Dual speed 1:11 Hybrid-Drive
- **Extras** Tube rings, end cap, carry case
- **Weight** 8.0kg
- **Supplier** 365 Astronomy
- **www** [www.365astronomy.com](http://www.365astronomy.com)
- **Tel** 020 3384 5187

WWW.THESECRETSTUDIO.NET X 6

The motto of Italian firm PrimaLuceLab is 'Aim high', so we were keen to find out how the relatively unknown manufacturer lives up to that ideal. PrimaLuceLab's AIRY APO120 refractor arrived on one of the few days of this summer when the weather, Moon, and short nights decided to play nicely together. Grabbing the precious opportunity we mounted the telescope immediately. All we knew at this point was it was a 4.75-inch, f/7.5 instrument, but we had a fair idea of what to expect from the doublet lens. Or at least that's what we thought.

The first target we observed was Jupiter, using our own premium 10mm eyepiece and a 2x Barlow lens. The view was quite remarkable, breathtaking in fact. The equatorial bands were crisp and sharp, the Great Red Spot stood out clearly, and there was not a trace of colour fringing or chromatic aberration. Jupiter just looked like a photograph, and a very good one at that.

With such accurate colour correction at hand we slewed around to view some of the more vibrant stars, starting with the blue and gold double star known as Albireo in Cygnus, then up to red giant Arcturus in Boötes, and eventually down to Mirach in

### SKY SAYS...

Jupiter's bands were crisp and sharp, and there was not a trace of colour fringing or chromatic aberration

Andromeda, a dazzling yellow star. Through the evening we viewed Mars and Saturn, again with a Barlow lens to increase magnification. Mars was a clear disc with good contrast on the darker regions and white at the poles, and the typical dusky pink surface, while Saturn displayed the Cassini Division within its rings and well-defined coloured banding on the planet, all without interference from colour halos. Looking back, our observing notes for Saturn end with "a glorious sight".

### The day after the night before

In the light of the next day we looked more objectively at the AIRY 120APO. It is supplied in a nice case, with matching tube rings, end cap, focuser and eyepiece holder, full instructions and even a four-year warranty, and as such you get the impression that this telescope has been prepared by somebody who is passionate about it. Each unit has a unique serial number, and the patented focuser is precisely machined with a smooth, fluid motion. The dew shield extends smoothly without tilting or slipping, and the twist and lock eyepiece holder rounds off a well put together package.

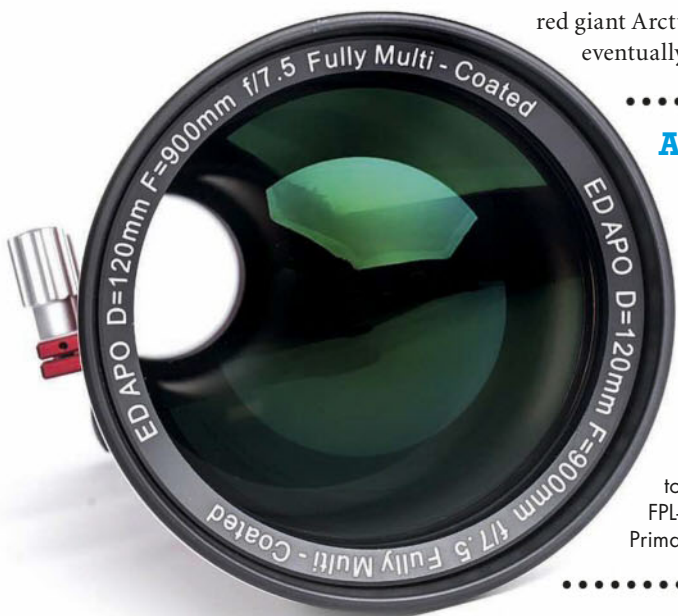
Of course all of this comes at a price, and the AIRY 120APO is certainly at the premium end of ▶

### APOCHROMATIC DOUBLET LENS

Normally when we talk about apochromatic telescopes we are discussing those with three lenses, or triplets. Apochromatic optics bring the three main colour wavelengths of light to the same point of focus, a feat that is more readily achieved with a triplet system. However the AIRY 120APO is a doublet, and uses just two lenses to bring the colours to focus. By using high quality FPL-53 glass for one of the elements, PrimaLuceLab has produced a

telescope that gives outstanding true colour views at the eyepiece, without a hint of colour fringes, even on the brightest objects.

For instance, we observed an almost full Moon, and carefully checked for any tell-tale blue halo around the bright edges, and there was none. Using our CCD camera we confirmed that red, green and blue wavelengths are brought into very close focus, on a par with results from premium triplet refractors. Doublets usually cool to ambient temperature more quickly than triplet lenses, and are less prone to aberrations caused by fluctuating temperatures.





## ROTATABLE ASSEMBLY

The whole focuser assembly can be rotated by loosening a thumbscrew, or the eyepiece or camera alone can be rotated. Not only does this allow for the accurate framing of photographic targets, it also allows the user to find the most comfortable viewing and focusing position on a variety of mounts.

## USER MANUAL

Bucking the trend for online only manuals, there is a detailed user guide with useful photographic diagrams to help with setting up the telescope for visual or photographic use, and a complete list of available accessories for the AIRY APO120. Contact and social media details for the company are included.



## FOCUSER

PrimaluceLab calls this a Hybrid-Drive focuser. The well-engineered mechanism is smooth like a Crayford, yet strong and non-flexing, with rack and pinion-style gearing. Precise focus adjustments are easily managed with the dual-speed action, which firmly locks in place. Helpful instructions are supplied for tuning if required.



## ON-AXIS LOCKING ACCESSORY HOLDER

Instead of the usual two or three thumbscrews to attach a diagonal or camera equipment to the optical tube, there is a simple clamp that locks and loosens with a single twist. The inner rings of the clamp apply even and firm pressure to accessories, holding them centrally.



# FIRST light

## CARRY CASE

The rigid and lockable padded case makes a useful accessory, ideal for transporting or safely storing the telescope when not in use. The case is 90x30x29cm, and being aluminium weighs only 4.3kg. There are handles on the top and ends of the case.



## SKY SAYS...

Now add these:

1. PrimaLuceLab 140mm PLUS Losmandy plate-dovetail bar
2. PrimaLuceLab EAGLE control unit
3. PrimaLuceLab 115mm PLUS guide rings

► the market. However the combination of almost perfect views, with a respectable 4.72-inch aperture and a useful 900mm of focal length, in a telescope weighing just 8kg, could place the AIRY 120APO on the radar of astronomers looking for their next or final upgrade.

We also took a few pictures with a DSLR and a colour CCD camera. These proved again that the optics allow accurate colours on stars, such as those within globular cluster M13, however we did note that focus has to be absolutely perfect for best results, and that as temperatures dropped at night we were frequently having to readjust this. Without using any of the optional correctors available for this instrument, the stars towards the edges of our APS-C sized DSLR started to stretch a little, as expected, but we were pleased to note that this was uniform across the four corners.

The on-axis locking assembly at the end of the focuser was a 1.25-inch fit on our review model but we have been informed that later versions will have the 2-inch version as standard and the 1.25-inch as an optional extra. In summary, the AIRY 120APO offers outstanding aberration-free views in a stylish telescope that is a sheer pleasure to use. **S**



▲ Single exposure of the Moon with a DSLR – highlighting the absence of a blue fringe, unlike standard doublets



▲ M13 imaged with a DSLR, stacked from 36 exposures of 35 seconds



▲ M27 imaged with a colour CCD camera, stacked from nine 10-minute exposures

## VERDICT

|                 |       |
|-----------------|-------|
| BUILD & DESIGN  | ★★★★★ |
| EASE OF USE     | ★★★★★ |
| FEATURES        | ★★★★★ |
| IMAGING QUALITY | ★★★★★ |
| OPTICS          | ★★★★★ |
| OVERALL         | ★★★★★ |



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# FIRST light

See an interactive 360° model of this camera at [www.skynightmagazine.com/skyris236c](http://www.skynightmagazine.com/skyris236c)



## Celestron Skyris 236C Solar System camera

A colour camera with a CMOS chip, capable of great planetary images

WORDS: MARTIN LEWIS

### VITAL STATS

- **Price** £585
- **Extras** C-mount to 1.25-inch adaptor, C-mount to CS-mount adaptor, USB 3.0 lead, software/driver CD, user manual
- **Software** iCap v2.3, RegiStax v6.1
- **Sensor** Sony Exmor IMX236 CMOS sensor
- **Pixels** 1920x1200, 2.8µm square
- **Dimensions** 42x42x39mm
- **Weight** 103g
- **Supplier** David Hinds
- **www** [www.celestron.uk.com](http://www.celestron.uk.com)
- **Tel** 01525 852696

**T**he Celestron Skyris 236C is a sensitive, high speed USB 3.0 digital video camera from the established collaboration between Celestron and The Imaging Source. Like most of the newest solar system imaging cameras on the market, this one has a CMOS-based optical sensing chip at its heart.

Planetary imaging cameras like those in the Skyris range record a video, the best frames of which can be aligned and stacked to produce a single master frame in which much of the blurring effects of our atmosphere have been averaged out. This image can be then sharpened with processing software to produce wonderfully detailed Earth-based images of our near neighbours in space.

The Skyris 236C is a one-shot colour camera: it has a colour filter matrix built into the front face of the chip, and this makes the process of colour imaging more straightforward. A monochrome version is also available (the 236M), which gives a higher resolution for each colour but requires shooting through separate red, green and blue filters to produce the final colour image.

The large 1,920x1,200-pixel chip of the 236C will capture fair images of the Sun and Moon, even though the 236M would be the better choice here with its higher effective resolution. We confined our testing

### SKY SAYS...

After processing we were left with a smooth and artefact-free Jupiter result showing lots of fine belt details

of the 236C to more colourful objects visible in the evening sky: the planets Jupiter, Mars and Saturn.

The camera can be run using control program iCap, which is supplied with the camera on a disc, but we preferred to use the more feature-rich freeware program FireCapture. After installing the 236C's drivers (also included on the disc) we had no issues getting the camera running on a Windows 7 laptop. For our tests, we attached the camera to an 8.75-inch, f/5.8 Newtonian telescope, adding a 2.5x Barlow lens and infrared-blocking filter to the setup.

### Battling the murk

On an evening of good seeing we imaged Jupiter in quite bright twilight; after processing we were left with a smooth and artefact-free result showing lots of small spots and fine belt details. Later on the same night we turned to Mars and Saturn. Both were well south of the celestial equator, reaching a maximum altitude of only 17° this year from the UK, and unfortunately this meant we had to capture them through a considerable thickness ▶

### AN ABUNDANCE OF PIXELS

The Skyris 236C has a generous chip for a planetary camera at 1,920x1,200 pixels. Although a monochrome camera is really the camera of choice for solar and lunar imaging due to its higher inherent resolution, if you wanted to experiment the big colour chip would also allow you to have a reasonable go at imaging these objects.

A large chip like this has few drawbacks as most modern cameras support the 'region-of-interest' feature, which allows you to collect data from just the part of the chip with the object in.

This significantly reduces file size and allows cameras with higher pixel count chips (like the 236C) to run at much faster speeds, limited primarily by the frame exposure time rather than the data transfer rate. The pixels in the chip are smaller than many of its competitors at only 2.8µm across, so the camera needs less optical amplification to produce the same final image size. This can be helpful for shorter focal ratio scopes such as Newtonians or short focus refractors as it allows the use of standard magnification Barlow lenses.





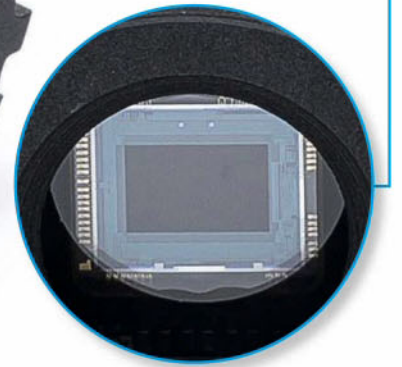
## BODY

The camera's body is small and lightweight and uses an attractive aluminium housing with heat fins to help keep the camera cool and minimise read noise. A screw hole for tripod mounting would have been useful for the occasions you might want to use the camera off the scope coupled to a suitable lens.



## CMOS NOT CCD

The Skyris 236C is a member of a growing number of Solar System video cameras that use a CMOS chip rather than the more traditional CCD. Recent technical advances mean that these chips are now often cheaper, faster and more sensitive than CCD chips.



## USB 3.0

USB 3.0 connectivity allows faster video data transfer rates when imaging and lets you gather more frames in a short space of time. The camera comes with a generous 3m USB 3.0 cable, which secures to the camera with thumbscrews. It also supports USB 2.0 if your computer is not USB 3.0 ready.



## MANUAL

The 15-page manual is well laid out and clear. It covers system requirements, driver and software installation, how to use the camera to capture videos and a section on how to process your captured videos. There are also some useful general tips on digital video imaging.





# FIRST light



## 1.25-INCH ADAPTOR

The kit comes complete with a 1.25-inch to C-mount adaptor, which screws to the front of the camera and allows you to insert it into a standard eyepiece holder. The adaptor is threaded for 1.25-inch filters, which is important as for the best performance you will need to attach your own infrared/ultraviolet-blocking filter when imaging.

### SKY SAYS...

Now add these:

1. Celestron Skyris infrared-blocking filter
2. Celestron USB to RS232 converter
3. Celestron 80mm guide scope

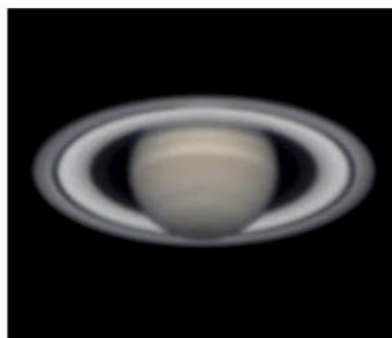
► of image-disturbing atmosphere. Their low altitude also amplified the prismatic dispersion caused by Earth's own atmosphere, and this had the potential to further smear colour and planetary detail. We hoped the good seeing would help us with the former problem whilst the latter issue was dealt with by adding a correctly tuned atmospheric dispersion corrector between the camera and the Barlow lens.

Mars, being such a high surface brightness object, allowed much shorter exposure times than Jupiter, which enabled us to make the most of the fast speed of the camera and run at a blistering 128fps – capturing nearly 8,000 frames in 60 seconds. The short exposures helped freeze the movement of the atmosphere and the high number of frames also helped by allowing us to select only the very best

frames for stacking. Again we were pleased by the final result for such a low altitude object.

Saturn has a much lower surface brightness than Mars or Jupiter, and to keep the exposures at a reasonable 33 milliseconds the gain had to be turned right up. Despite this we managed to produce another good image, clearly showing the Cassini Division and allowing us to glimpse the globe through the gap in the rings. We saw no lines of background noise in our image, which was good news as these can appear in some cameras when they are run at close to maximum gain.

The Skyris 236C is a member of the new generation of fast, sensitive, low noise and large-area CMOS-based digital video cameras, and is capable of great planetary images in good conditions. We were very pleased with the images it produced, its straightforward ease of use, and its robust and attractive build. **S**



▲ Saturn, stacked from 1,500 frames captured in a 33-millisecond exposure



▲ Jupiter, stacked from 1,100 frames captured in a 15.9-millisecond exposure

## VERDICT

|                 |       |
|-----------------|-------|
| BUILD & DESIGN  | ★★★★★ |
| CONNECTIVITY    | ★★★★★ |
| EASE OF USE     | ★★★★★ |
| FEATURES        | ★★★★★ |
| IMAGING QUALITY | ★★★★★ |
| OVERALL         | ★★★★★ |





# Northumberland National Park



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# FIRST light

See an interactive 360° model of this accessory at [www.skyatnightmagazine.com/polemaster](http://www.skyatnightmagazine.com/polemaster)



## QHYCCD PoleMaster electronic polarscope

An innovative product that makes polar aligning much less of a burden

WORDS: PETE LAWRENCE

### VITAL STATS

- **Price** £278
- **Camera** 11x8° field of view, 30-arcsecond resolution, adjustable gain and exposure
- **Precision** Polar alignment within 30 arcseconds
- **Interface** USB 2.0 (cable supplied)
- **Dimensions** 65mm long, 48mm max diameter
- **Weight** 135g (camera unit)
- **OS supported** Windows 7, 8 and 10; Mac OS beta available
- **Supplier** Modern Astronomy
- **www.** [modernastronomy.com](http://modernastronomy.com)
- **Tel** 020 8763 9953

▼ The PoleMaster's control software offers the ability to change sensitivity, gain and more

**E**quatorial mounts require accurate polar alignment to work properly and QHYCCD's PoleMaster is designed to help you achieve just that without fuss or physical contortions.

If you're a visual observer then a rough polar alignment by eye is normally sufficient, but imaging has greater demands and inaccuracies will show up as misshapen stars or unwanted star trailing.

### CONTROL SOFTWARE

The PoleMaster hardware is complemented by software that guides you through the polar alignment process. Drivers for the camera can be downloaded from the QHYCCD website and we had no problem getting the camera recognised on our Windows 7 test system.

The main control software has had several updates to introduce new features such as southern hemisphere alignment and support for low latitude polar alignments, which are affected by atmospheric refraction.

A well-designed setup wizard guides you through the steps required to get your mount aligned. This simple step-by-step process is pretty painless and very quick to perform, especially after having done it a few times. The camera's sensitivity can be adjusted via exposure and gain controls, which is useful if you live in a light polluted area. We had no problem identifying Polaris or matching the PoleMaster's software alignment templates to the image shown on screen.

The software currently runs under Windows 7, 8 and 10, but not Vista. According to the manual, there's also a beta Mac/OS version available too.

There are generally two forms of tracking used in astrophotography: unguided just uses the mount's right ascension (RA) drive and is the most demanding in terms of polar alignment accuracy, while guided astrophotography introduces the closed-loop technique of autoguiding. This is where a camera feeds an image to a computer, which controls the mount. If the guide star on the camera's image moves out of position, the computer issues the necessary instruction to correct the mount's position. The PoleMaster is ideal for setting up a mount for either method.

The whole set up process is rather simple. The PoleMaster's camera attaches to the top of an equatorial mount's RA axis via an adaptor plate. The device doesn't have to be co-incident with the mount's polar axis. A growing number of adaptors are available and we tested it with a Sky-Watcher AZ EQ6-GT mount, which already has a polar alignment scope installed along the polar axis.

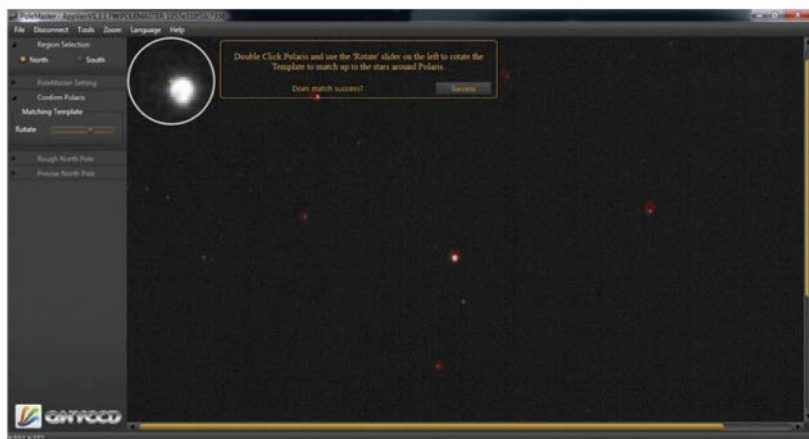
### Embracing the new

Normally we'd sight Polaris through this scope, achieving alignment by placing Polaris and at least two field stars in the indicated positions of an illuminated reticule display. Although we've done this successfully many times, it's not the most comfortable of procedures as it requires kneeling on the ground to sight up the scope. The PoleMaster eliminates this need. Once the adaptor plate has been fitted, you only need to rough align the mount, attach the PoleMaster to the adaptor plate, connect it to a computer and run the polar alignment software wizard.

The PoleMaster's camera has a large field of view and we found Polaris easily every time. Once located, we double-clicked on Polaris and had to rotate an overlay template to match some brighter stars in the field. This is done with a slider control, fine-tuned via the keyboard's cursor keys. Once ▶

### SKY SAYS...

The PoleMaster's camera has a large field of view and we found Polaris easily every time





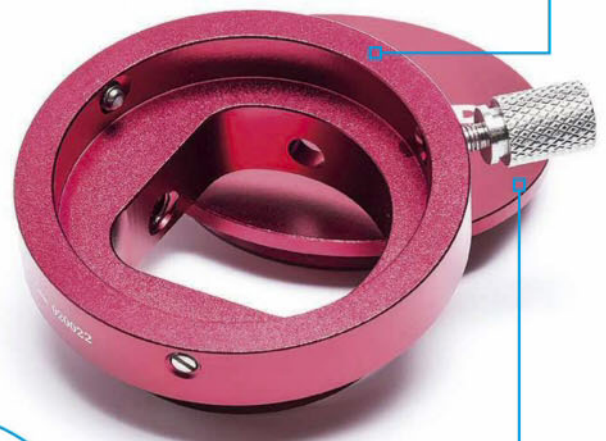
## POLEMASTER CAMERA

The PoleMaster's camera is a small unit that fits snugly into its adaptor plate. Once in place, it can image a region of sky measuring  $11 \times 8^\circ$  – large enough to locate Polaris after a rough align. The camera lens is pre-focused at infinity but can be re-focused should the need arise.



## ADAPTOR PLATE

The PoleMaster is normally sold with a mount-specific adaptor kit. Other adaptors can be bought separately, typically for less than £40. For our Sky-Watcher AZ EQ6-GT mount, a ring-adaptor locked on the top of the mount via a grub screw arrangement. A thumbscrew then locks the camera securely into the adaptor.



## USB CONNECTION

The camera requires a modest USB 2.0 connection made via a 1.8m USB cable, terminated at the computer end by a USB type-A plug and at the other by a mini-B USB connector. If anything, the cable could have been a bit longer. The camera plug has two securing screws, used to ensure it doesn't fall out.



## ADAPTOR PLATE COVER

The camera can be left in place on its adaptor plate or removed and packed away in its foam-lined tin. With no camera in place, a small metal cover is provided which can be snugly fitted inside the adaptor ring and locked in position by the adaptor plate's thumbscrew.





# FIRST light

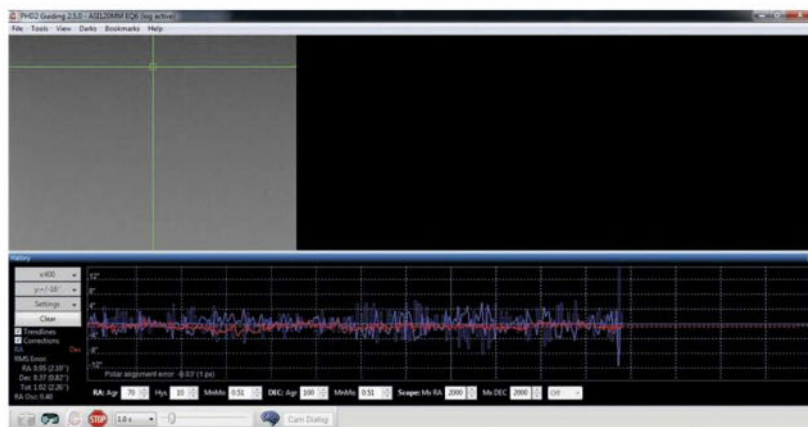


## SKY SAYS...

Now add these:

1. QHY5L-II mono guide camera
2. QHY8L imaging camera
3. Adaptors for other mounts

▼ PHD Guiding's drift align plot, which measures declination accuracy after PoleMaster alignment



## CAMERA COVER AND LANYARD

The camera's cover screws in place to protect the lens. This is useful if, for example, you're out for a long period in damp conditions where the PoleMaster may eventually dew over. A short lanyard is provided which screws into the cap to secure it to the camera body so it can't be lost.



► complete the mount must be rotated by at least 30° in RA, which can be done manually or via the mount's drive. After repeating this step one more time, the PoleMaster indicates where you need to move Polaris, via the mount's altitude and azimuth adjusters, to achieve alignment. The final stage displays two coloured circles that need to be overlaid. Once done, you're good to go. If your alignment is lost throughout the night, the PoleMaster allows you to correct on the fly.

It's great not having to kneel down to do this and the process is really quick, especially after you've worked your way through it a couple of times. On our first night out with the PoleMaster we found we were imaging just minutes after setting it up. Under normal alignment using the AZ EQ6-GT's in-built polar alignment scope we'd be happy with 60- to 90-second exposures. With PoleMaster we were able to perform 300-second exposures quite happily.

Our view was reinforced when we used the PoleMaster for solar imaging the following day.

After normal alignment through the mount's own polarscope, we found that high resolution solar views would still have a tendency to drift out of frame after 15-20 minutes. After aligning with the PoleMaster, the feature we were following remained in the view even after several hours of unguided tracking.

We used the freeware PHD Guiding to monitor a star's position after PoleMaster alignment. The results were impressive and showed we had achieved polar alignment to within the PoleMaster's quoted 30-arcsecond accuracy. The most accurate way to align an equatorial mount is to use a technique called drift alignment. Done properly, this should allow better accuracy than the PoleMaster, but it is more time consuming. It can also be especially daunting to newcomers. If you do require extra accuracy, drift aligning after PoleMaster alignment really speeds this process up. For Go-To scopes, the use of the PoleMaster eliminates the need for complex sky modelling so a one-star align should be all that's needed.

We think that QHYCCD have come up with an excellent product here which really takes the sting out of having to polar align. The accuracy of the device meant that polar aligning with the PoleMaster was more a pleasure than a chore. **S**

## VERDICT

|                |       |
|----------------|-------|
| ACCURACY       | ★★★★★ |
| BUILD & DESIGN | ★★★★★ |
| CONNECTIVITY   | ★★★★★ |
| EASE OF USE    | ★★★★★ |
| FEATURES       | ★★★★★ |
| OVERALL        | ★★★★★ |



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# Books

New astronomy and space titles reviewed

## RATINGS

- ★★★★★ Outstanding  
 ★★★★★ Good  
 ★★★☆☆ Average  
 ★★☆☆☆ Poor  
 ★☆☆☆☆ Avoid

## Calculating the Cosmos: How Mathematics Unveils the Universe

BOOK OF THE MONTH

Ian Stewart  
 Profile Books  
 £20 • HB

In 1846, French astronomer Charles-Eugene Delauney began calculating the motion of the Moon. The task took him over 20 years and was published in two volumes, each more than 900 pages long, the second containing the mathematical formulae alone! In his new book, mathematician Ian Stewart manages to cram the entire mathematical history of the Universe into just 350 pages, and with hardly any equations.

Since ancient times, mathematics and astronomy have informed each other. Our advances in space exploration and our understanding of the Universe are based on technology, engineering and science, but it is mathematics that has both underpinned and led the way. Mathematics informs astronomy and predicts

astronomical events, just as astronomical objects and events have influenced developments in mathematics. This is the story that Stewart sets out to tell.

The author does not hold the reader's hand and assumes some prior knowledge, so attention is required. You can be following along quite happily, but if you don't concentrate can easily find yourself in a tangle with no option but to retrace your steps. Having said that, there is plenty here

to hold the attention. *Calculating the Cosmos* takes us through each topic, from gravity and the formation of the stars through to spacetime and multiverses. We journey from the earliest observations, calculations and theories, learning how our knowledge grew, often taking

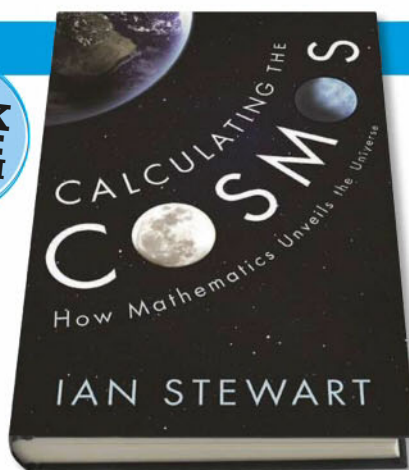
three steps forward and two steps back. We discover the conventional views and alternative hypotheses, speculations, controversies, fudges, rivalries, assumptions and unresolved issues. It is bang up to date too, including the latest discovery of gravitational waves.

One or two of the illustrations could be a little clearer perhaps, but overall the book does an excellent job of both

explaining and entertaining. The author makes you think about familiar subjects in a new way and is very good at filling in any gaps in your knowledge, while also pointing out those areas that need further research. I definitely need to brush up on my Penrose diagrams!

★★★★★

JENNY WINDER is an astronomer and science writer



### TWO MINUTES WITH IAN STEWART

Is it correct to say that mathematics, more than physics, underpins the

workings of the Universe?

Historically they've gone hand in hand. Physics develops mathematical models of the real world to help us understand it, mathematics tells us what those models imply. But each does other things: physics is supported by experiments, and mathematics has developed its own 'inner world' of concepts that arise from pure curiosity as well as applications.

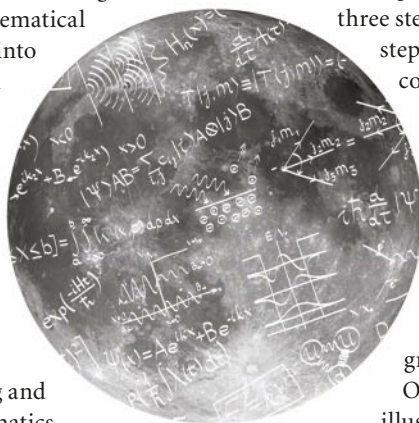
### What inspired you to apply your love of mathematics to cosmology?

At primary school I was fascinated by the stars and planets. Later I got interested in mathematics and became a mathematician. My research area, dynamical systems, was originally inspired by Newton's discovery of the law of gravity. I work on symmetries and biological applications, but I never lost my childhood love of astronomy.

### What questions does the book seek to answer?

My main aim was to explore big questions and help readers to make up their own minds, rather than to give answers. But to avoid copping out I do sometimes make my own opinion clear – although I may be wrong! As a science-fiction fan I love the idea of alternative universes coexisting with ours, but I agree with George Ellis [the renowned cosmologist] that most 'multiverse' ideas currently have no explanatory power, so perhaps science-fiction is where they should remain. I also tackle alien life, inflation, dark energy, and the many-worlds interpretation of quantum mechanics.

IAN STEWART is emeritus professor of mathematics at the University of Warwick

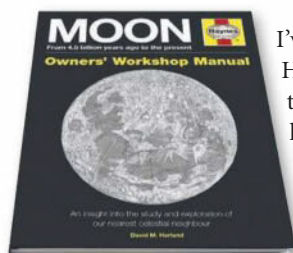


Maths and astronomy owe more to each other than you might think



## Moon: Owners' Workshop Manual

David M Harland  
Haynes Publishing  
£22.99 • HB



I've enjoyed Haynes's recent titles covering space hardware, from the Saturn V rocket to the Voyager probes, but to my knowledge

David M Harland's book covers their biggest subject yet: an entire world.

Despite being on our cosmic doorstep and ideally placed for backyard observing, Earth's Moon is often overlooked in favour of the more 'interesting' Solar System objects such as tantalising Mars and glamorous Jupiter. Yet our satellite played a key role in our understanding of our place in the Solar System, how planets and similar objects evolve, and indeed how we 'do' astronomy as a science. It's therefore a pleasure to find a book devoted to the

subject: despite its title, this Moon manual is at heart a history of these developments.

Beginning in classical times with the Moon's role in timekeeping, Harland traces the story to the lessons of the Apollo landings and beyond, to the work of robot missions such as Lunar Prospector, GRAIL and Chang'e 3. Particularly intriguing is the history of Earth-based efforts to map the Moon (did you know that Leonardo da Vinci drew one of the first lunar maps?), and coverage of the oft-overlooked Soviet lunar landers of the 1970s. Even when discussing the various lunar missions, however, Harland's focus is on the discoveries they made and the clues they give us about lunar history.

Clearly written and lavishly illustrated throughout, an array of archive images and photographs is accompanied by simple diagrams to put some of the more complex ideas into context. I've just one complaint, but sadly it's a big one: the absence of an index severely limits the manual's usefulness as reference book.

★★★★★

GILES SPARROW *is a science writer and fellow of the Royal Astronomical Society*

## Project Mercury

Eugen Reichl  
Schiffer  
£17.50 • HB



Mercury was the NASA programme that put the first Americans into space in the early 1960s. This book, translated from a German original, manages

to tell the story of those seven manned missions and their associated test missions in a detailed yet very readable way. Its author, Eugen Reichl, is on the staff of European aerospace giant EADS and has written about a number of aspects of spaceflight. A companion work on Mercury's follow-up programme, Gemini, is also available in English from the same publisher.

*Project Mercury* is bound to please hardcore space exploration fans, as it features technical details of the rockets and space capsules alongside easy-flowing narrative. We learn of every aspect, not only of the human flights, but also of those made by two chimps, Ham and Enos: for example how the animal astronauts were given tasks to complete, with banana pellet treats for a job well done and a mild electric shock for a failure.

The book's German origin is evident from the first page. It reveals the Mercury programme's roots as the successful launch of Aggregate rockets from Peenemünde, without feeling the need to tell readers until later on that this is in Germany. The reader is reminded, however, that the Aggregate was renamed the Vengeance Weapon 2 (V-2) and killed several thousand people.

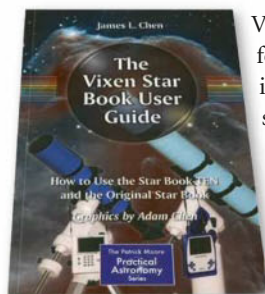
The amount of information in this well-illustrated volume is impressive. Space enthusiasts interested in a detailed history of America's manned space programme will be keen to have a copy of it on their bookshelves.

★★★★★

PAUL SUTHERLAND *is a space writer and journalist*

## The Vixen Star Book User Guide

James L Chen  
Springer  
£16.99 • PB



Vixen is renowned for the quality of its user manuals so, at first glance, this independent user guide seems like an unusual choice of subject.

However, there is no substitute for tapping into the knowledge acquired by an experienced user like James L Chen for discovering how a piece of equipment works in the real world.

The book covers both the original retro-style Star Book and the more conventional looking Star Book Ten. However, there are also sections covering their offshoot reduced-function handsets, the Star Book One and Star Book 'S'.

Initial setting up – which is often the cause of many issues with Go-To telescope systems – is covered in some depth with hints and tips to avoid the potential pitfalls that can stop an observing session in its tracks. This is followed by step-by-step walkthroughs of all the available functions on each handset. The text is written in a relaxed style with the odd anecdote slipped in for good measure and includes a wealth of invaluable information, although there is some unnecessary repetition and it could have done with a final edit to remove annoying typographical errors.

Updating firmware and other data often fills users with dread but a comprehensive set of instructions for carrying this out is included. However, strangely, Chen confesses that he cannot verify the procedures outlined as they can only be performed by a PC and he is a Mac user. Full of colour illustrations and with pleasantly readable text, any new Star Book user would gain much confidence from reading this book.

★★★★★

STEVE RICHARDS *is BBC Sky at Night Magazine's Scope Doctor*



# Gear

Elizabeth Pearson rounds up the latest astronomical accessories



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## WHAT I REALLY WANT TO KNOW IS...

## Why are some black hole jets so strong?



**Alexander Tchekhovskoy** has been investigating why some active galaxies pack much more of a punch than others

INTERVIEWED BY PAUL SUTHERLAND

**T**he supermassive black holes at the centre of galaxies are often thought of as absorbing everything thrown at them, but they actually spew

out quite a bit of what heads their way. Some of this is spat out in the form of jets – collimated streams of hot, ionised gas.

About a tenth of active galactic nuclei are seen to have jets of gas spurting in opposite directions from the core, propelled by the twisting magnetic fields of the rotating black hole, which can be as massive as several billion Suns.

A long-standing puzzle has been that some of these jets shine like brilliant beacons visible across the Universe – the jet in the galaxy Cygnus A, 600 million lightyears from Earth, is a famous example – while others fizzle out before they get far from their home galaxy's surroundings. I've been using supercomputers to try to find out why.

As a black hole rotates, it winds up associated magnetic field lines. This rotation propagates and carries energy away along the field lines, rather like the wave you can shake along a climbing rope in a gym. The jets produced take energy from the black hole's rotation and transport it outwards, where it drills into surrounding material called the ambient medium.

### A morphological mystery

Astronomers have found two jet shapes, or morphologies. One is elongated, very thin and ends up with two bright hotspots (called lobes) where the jets impinge on the ambient medium. The other looks like it is falling apart and disappearing into nothing. So why do some jets behave differently from others?

There have been many attempts in the past 40 years to reproduce the jets using computers. However, while it has been relatively easy to model the jets' long and sharp shape, it has been – and still is – a challenge to produce the other kind of morphology, where the jet is wobbly and falling apart. Attempts were contrived to put giant stars in the paths of the

jets in order to simulate the disruption observed.

With a colleague, I set out to understand what would change if we included magnetic fields in the simulation.

Scientists don't really know how strong these magnetic fields are.

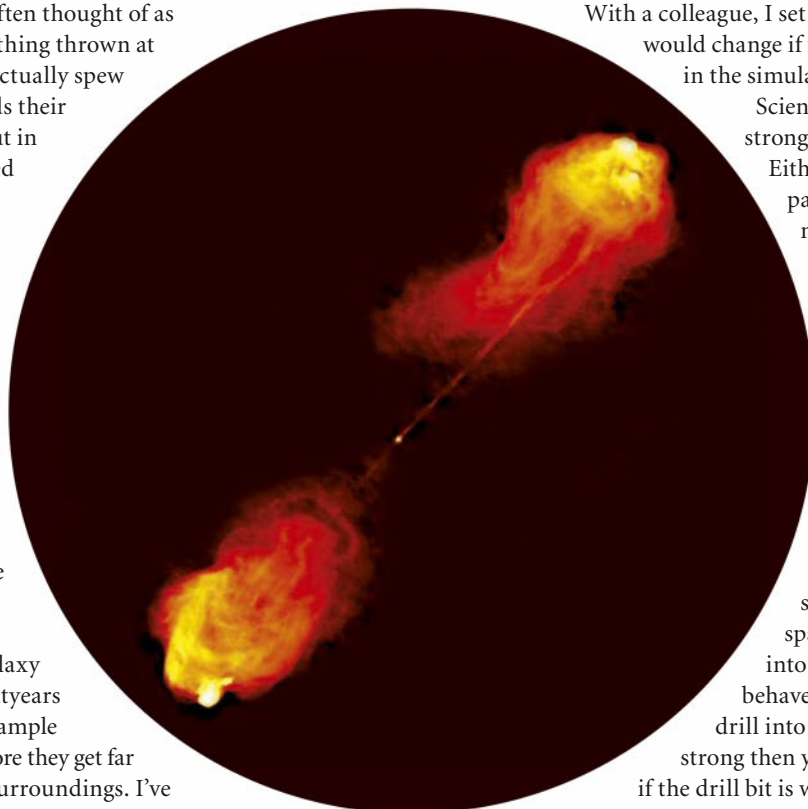
Either they are weakish and so passively stretched by the jet's motion or they are the driving force that determines the dynamics of the jets. We decided to take the extreme approach and ask what happened if these jets are dominated by the magnetic fields.

We initiated the jets by rotating a magnetised sphere, which is very similar to a black hole, to simulate the spinning of spacetime. Once the jet runs into the ambient medium it behaves like a drill. If you try to drill into a wall and your drill bit is strong then you will go into the wall, but if the drill bit is wimpy then it can break off and you'll have to replace it.

We found that this is what the jets do if they are weak: they are not good enough to drill through the medium and break up. New pieces of jets are produced by the rotation and those break up too. Our simulation found that the strong jets propagated just fine but the weak jets got stuck.

A special property of magnetic field lines is that they have tension, like a spring. Squished between your thumb and index finger, a spring will tend to fly sideways. This is precisely the sort of instability that these natural structures can go through. If the spring is strong you will squish it but it won't fly away, but if it is weaker it is more likely that it will be unstable and shoot sideways.

Unstable jets contribute to black hole feedback, a reaction from the material around the black hole that tends to slow its intake of gas and thus its growth. Our next step will be to refine the simulations and to compare the results with actual black hole jets observed in nature. This will allow us to better understand how supermassive black holes and galaxies grow. **S**



The strong jets fired from the black hole in Cygnus A end in huge radio lobes

#### ABOUT ALEXANDER TCHEKHOVSKOY

Alexander 'Sasha' Tchekhovskoy is a theoretical astrophysicist at the University of California, Berkeley, where his interests include high-energy processes powered by black holes and neutron stars.





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# The Southern Hemisphere in September



With Glenn Dawes

## WHEN TO USE THIS CHART

1 SEP AT 00:00 UT  
15 SEP AT 23:00 UT  
30 SEP AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude  $-35^\circ$  south.

## SEPTEMBER HIGHLIGHTS

It's a month of lunar conjunctions. In the evening twilight on the 3rd the crescent Moon is  $3^\circ$  below Venus, with Jupiter and Mercury nearby, while the 8th and 9th see the first quarter Moon visit Saturn, Mars and mag. +1.1 Antares (Alpha ( $\alpha$ ) Scorpii). In the morning sky on the 22nd, the near third quarter Moon resides within the Hyades, only  $2^\circ$  from mag. +0.9 Aldebaran (Alpha ( $\alpha$ ) Tauri). On the 28th it is  $1.5^\circ$  from mag. +1.4 Regulus (Alpha ( $\alpha$ ) Leonis) and  $6^\circ$  from Mercury on the 29th.

## STARS AND CONSTELLATIONS

This is a great time of year: the nights are long and as evening twilight ends the traditional winter gems – the Milky Way and its associated star clusters and nebulae – are still well showcased. But as early as midnight the sky begins to become more summery. The eastern half is now somewhat extragalactic, with the remaining bright members of the Local Group of galaxies on show. The naked-eye examples are the two breathtaking Magellanic Clouds and the Andromeda Galaxy.

## THE PLANETS

September opens with Mercury, Jupiter and Venus forming a triangle low in the evening twilight. Mercury, by far the faintest, is also the first to depart, sinking into the Sun's glare after the first week. Jupiter soon follows, dropping away from

brilliant Venus and lost by mid month. Venus remains low in the west, setting around 20:00 EST. Higher in the sky, Saturn continues its liaison with mag. +1.1 Antares (Alpha ( $\alpha$ ) Scorpii), forming a triangle with Mars. These planets set around midnight.

## DEEP-SKY OBJECTS

High in the northern sky, below the inverted 'smile' of Capricornus, lies the obscure western extremity of Aquarius. This area is home to two interesting but lesser-known Messier objects. Just  $3.3^\circ$  above mag. +3.8 Epsilon ( $\epsilon$ ) Aquarii is globular cluster M72 (RA 20h 53.4', dec.  $-12^\circ 32'$ ; pictured). It is 3 arcminutes in diameter and has a broad core. This is a classic fuzzy ball for a telescope; you'll need an aperture



of 8 inches or more to start resolving stars on its edge.

Look  $1.3^\circ$  east from M72 to find M73, an asterism consisting of just four stars. Arranged in a Y shape and fitting within a 1-arcminute circle, they are most distinctive in a wide field (low power) eyepiece. The top stars are the brightest (mag. +10.2 and +11.0) with the other two close to mag. +12.0.

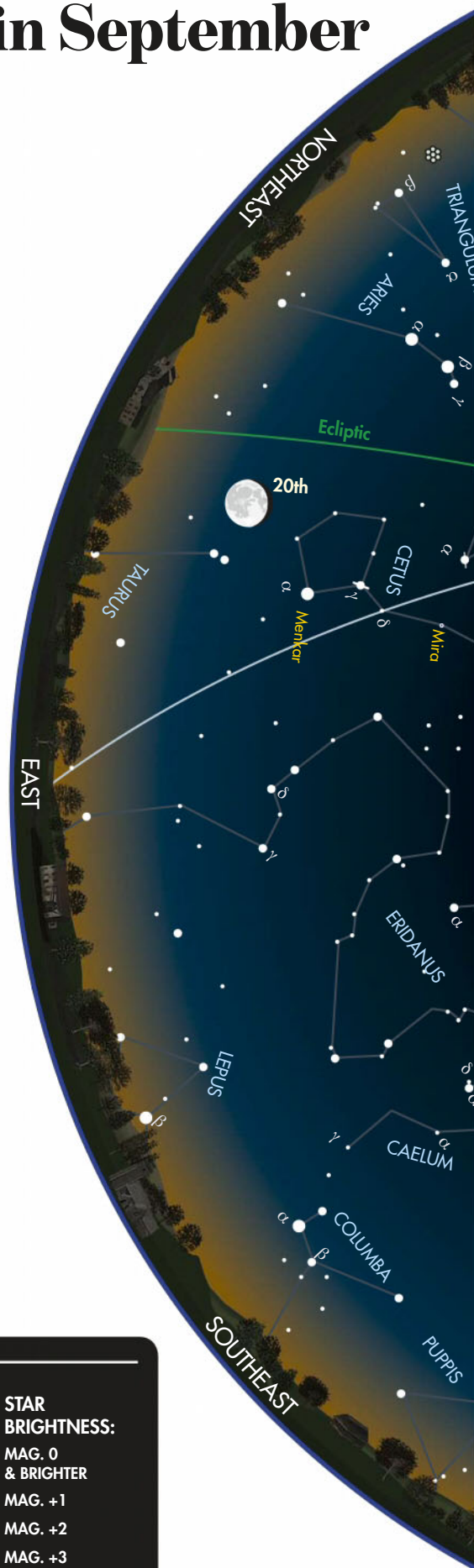
## CHART KEY

GALAXY  
 OPEN CLUSTER  
 GLOBULAR CLUSTER  
 PLANETARY NEBULA

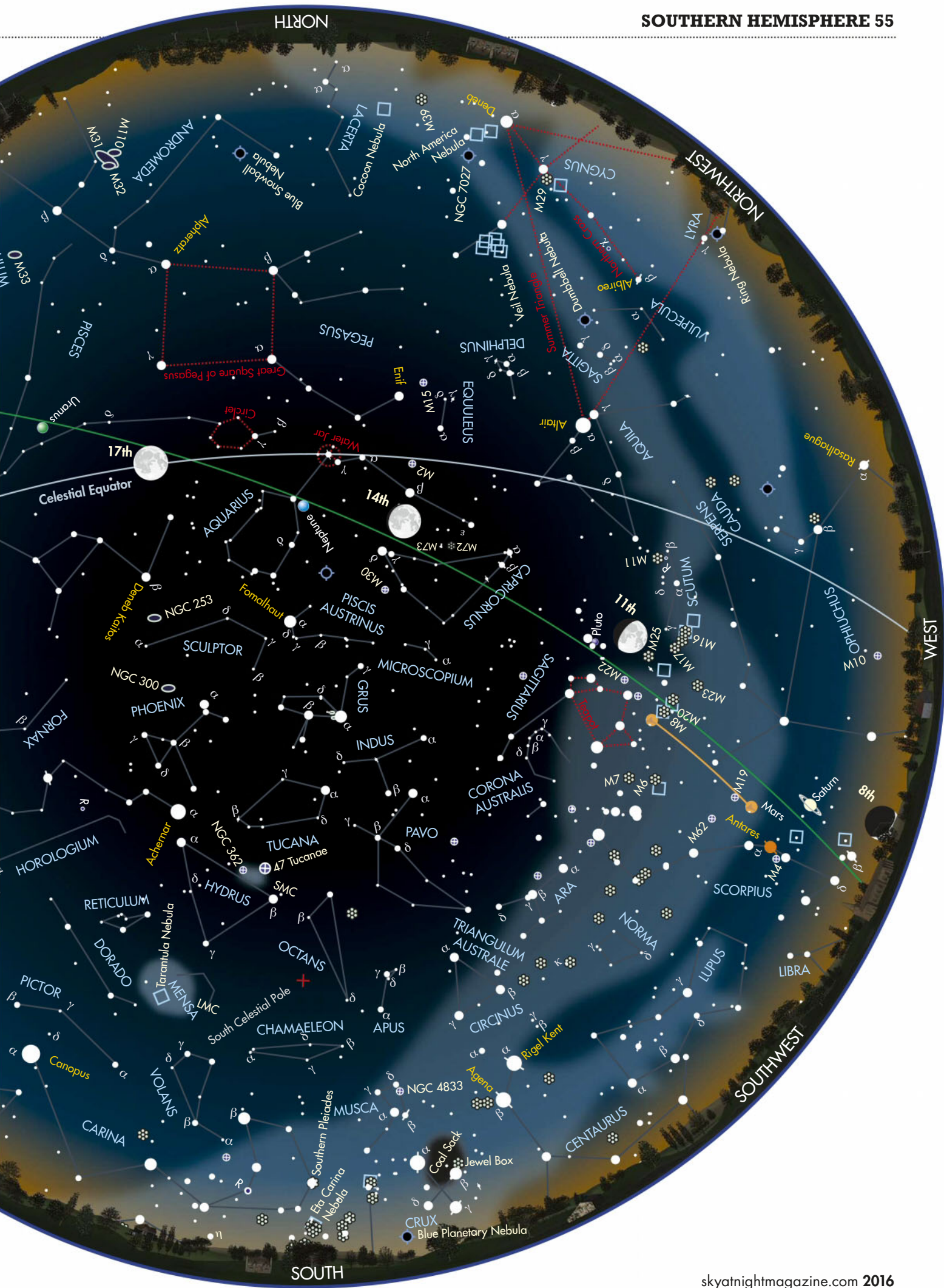
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